INTRODUCTION TO BASIC MANUFACTURING PROCESSES AND WORKSHOP TECHNOLOGY

PREFACE

Manufacturing and workshop practices have become important in the industrial environment to produce products for the service of mankind. The knowledge of manufacturing practices is highly essential for all engineers and technocrats for familiarizing themselves with modern concepts of manufacturing technologies. The basic need is to provide theoretical and practical knowledge of manufacturing processes and workshop technology to all the engineering students. Therefore, an attempt has been made through this book to present both the theoretical and practical knowledge of these subjects. Considering the general needs of engineering students in the country and the fact that they hardly get any exposure to hand tools, equipments, machines and manufacturing setups, a basic course in manufacturing science remains a core subject for all the branches of engineering. This book covers most of the syllabus of manufacturing processes/technology, workshop technology and workshop practices for engineering diploma and degree classes prescribed by different universities and state technical boards. While preparing the manuscript of this book, the examination requirements of the engineering students have also been kept in mind. The book is written in very simple language so that even an average student can easily grasp the subject matter. Some comparisons have been given in tabular form and the stress has been given on figures for better understanding of tools, equipments, machines and manufacturing setups used in various manufacturing shops. The contents include exposure to bench work and fitting, smithy and forging, sheet metal work, wood and wood working, casting, welding and machine shop practices. At the end of each chapter, a number of questions have been provided for testing the student's understanding about the concept of the subject. The whole text has been organized in twenty six chapters.

The first chapter presents the brief introduction of the subject with modern concepts of manufacturing technology needed for the competitive industrial environment. Chapter 2 provides the necessary details of plant and shop layouts. General industrial safety measures to be followed in various manufacturing shops are described in detail in chapter 3.

Chapters 4–8 provide necessary details regarding fundamentals of ferrous materials, non-ferrous materials, melting furnaces, properties and testing of engineering materials and heat treatment of metals and alloys.

Chapters 9–13 describe various tools, equipments and processes used in various shops such as carpentry, pattern making, mold and core making, foundry shop. Special casting methods and casting defects are also explained at length.

Chapters 14–16 provide basic knowledge of mechanical working of metals. Fundamental concepts related to forging work and other mechanical working processes (hot and cold working) have been discussed at length with neat sketches.

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CHAPTER

INTRODUCTION

1.1 INTRODUCTION

Manufacturing is the backbone of any industrialized nation. Manufacturing and technical staff in industry must know the various manufacturing processes, materials being processed, tools and equipments for manufacturing different components or products with optimal process plan using proper precautions and specified safety rules to avoid accidents. Beside above, all kinds of the future engineers must know the basic requirements of workshop activities in term of man, machine, material, methods, money and other infrastructure facilities needed to be positioned properly for optimal shop layouts or plant layout and other support services effectively adjusted or located in the industry or plant within a well planned manufacturing organization.

The complete understanding of basic manufacturing processes and workshop technology is highly difficult for any one to claim expertise over it. The study deals with several aspects of workshops practices also for imparting the basic working knowledge of the different engineering materials, tools, equipments, manufacturing processes, basic concepts of electro-mechanical controls of machine tools, production criteria's, characteristics and uses of various testing instruments and measuring or inspecting devices for checking components or products manufactured in various manufacturing shops in an industrial environment. It also describes and demonstrates the use of different hand tools (measuring, marking, holding and supporting tools, cutting etc.), equipments, machinery and various methods of manufacturing that facilitate shaping or forming the different existing raw materials into suitable usable forms. It deals with the study of industrial environment which involves the practical knowledge in the area of ferrous and non ferrous materials, their properties and uses. It should provide the knowledge of basic workshop processes namely bench work and fitting, sheet metal, carpentry, pattern making, mould making, foundry, smithy, forging, metal working and heat treatment, welding, fastening, machine shop, surface finishing and coatings, assembling inspection and quality control. It emphasizes on basic knowledge regarding composition, properties and uses of different raw materials, various production processes, replacement of or improvement over a large number of old processes, new and compact designs, better accuracy in dimensions, quicker methods of production, better surface finishes, more alternatives to the existing materials and tooling systems, automatic and numerical control systems, higher mechanization and greater output.

1.2 SCOPE OF STUDY

Today's competitive manufacturing era of high industrial development and research, is being called the age of mechanization, automation and computer integrated manufacturing. Due to new researches in the manufacturing field, the advancement has come to this extent that every different aspect of this technology has become a full-fledged fundamental and advanced study in itself. This has led to introduction of optimized design and manufacturing of new products. New developments in manufacturing areas are deciding to transfer more skill to the machines for considerably reduction of manual labor. The scope of the subject of workshop technology and manufacturing practices is a extremely wide as it specifies the need of greater care for man, machine, material and other equipments involving higher initial investment by using proper safety rule and precautions. The through and deep knowledge in the course of study of this important subject is therefore becoming essential for all kinds of engineers to have sound foundation in their profession. Therefore the course of study of this subject provides a good theoretical background and a sound practical knowledge to the engineering students and workshop staff. One should also be aware of the following terms for better understanding of the scope of the study

1.3 MANUFACTURING ENGINEERING

Manufacturing is derived from the Latin word manufactus, means made by hand. In modern context it involves making products from raw material by using various processes, by making use of hand tools, machinery or even computers. It is therefore a study of the processes required to make parts and to assemble them in machines. Process Engineering, in its application to engineering industries, shows how the different problems related to development of various machines may be solved by a study of physical, chemical and other laws governing the manufacturing process. The study of manufacturing reveals those parameters which can be most efficiently being influenced to increase production and raise its accuracy. Advance manufacturing engineering involves the following concepts—

1. Process planning.
2. Process sheets.
3. Route sheets.
4. Tooling.
5. Cutting tools, machine tools (traditional, numerical control (NC), and computerized numerical control (CNC).
6. Jigs and Fixtures.
7. Dies and Moulds.
8. Manufacturing Information Generation.
9. CNC part programs.
10. Robot programmers.
11. Flexible Manufacturing Systems (FMS), Group Technology (GT) and Computer integrated manufacturing (CIM).

1.4 PRODUCTION PROCESS

It is the process followed in a plant for converting semi- finished products or raw materials into finished products or raw materials into finished products. The art of converting raw

material into finished goods with application of different types of tools, equipments, machine tools, manufacturing set ups and manufacturing processes, is known as production. Generally there are three basic types of production system that are given as under.

1. Job production
2. Batch production
3. Mass production

Job production comprises of an operator or group of operators to work upon a single job and complete it before proceeding to the next similar or different job. The production requirement in the job production system is extremely low. It requires fixed type of layout for developing same products.

Manufacturing of products (less in number say 200 to 800) with variety of similar parts with very little variation in size and shape is called batch production. Whenever the production of batch is over, the same manufacturing facility is used for production of other batch product or items. The batch may be for once or of periodical type or of repeated kinds after some irregular interval. Such manufacturing concepts are leading to GT and FMS technology. Manufacturing of products in this case requires process or functional layout.

Where as mass production involves production of large number of identical products (say more than 50000) that needs line layout type of plant layout which is highly rigid type and involves automation and huge amount of investment in special purpose machines to increase the production.

1.5 PROCESS PLANNING

Process planning consists of selection of means of production (machine-tools, cutting tools, presses, jigs, fixtures, measuring tools etc.), establishing the efficient sequence of operation, determination of changes in form, dimension or finish of the machine tools in addition to the specification of the actions of the operator. It includes the calculation of the machining time, as well as the required skill of the operator. It also establishes an efficient sequence of manufacturing steps for minimizing material handling which ensures that the work will be done at the minimum cost and at maximum productivity. The basic concepts of process planning are generally concerned with the machining only. Although these concepts may also be extended to other processes such as casting, forging, sheet metal forming, assembling and heat treatment as well.

1.6 MANUFACTURING PROCESS

Manufacturing process is that part of the production process which is directly concerned with the change of form or dimensions of the part being produced. It does not include the transportation, handling or storage of parts, as they are not directly concerned with the changes into the form or dimensions of the part produced.

1.7 CLASSIFICATION OF MANUFACTURING PROCESSES

For producing of products materials are needed. It is therefore important to know the characteristics of the available engineering materials. Raw materials used manufacturing of products, tools, machines and equipments in factories or industries are extracted from ores. The ores are suitably converted the metal into a molten form by reducing or refining processes

in foundries. This molten metal is poured into moulds for providing commercial castings, called ingots. Such ingots are then processed in rolling mills to obtain market form of material supply in form of bloom, billets, slabs and rods. These forms of material supply are further subjected to various manufacturing processes for getting usable metal products of different shapes and sizes in various manufacturing shops. All these processes used in manufacturing concern for changing the ingots into usable products may be classified into six major groups as primary shaping processes, secondary machining processes, metal forming processes, joining processes, surface finishing processes and processes effecting change in properties. These are discussed as under.

1.7.1 Primary Shaping Processes

Primary shaping processes are manufacturing of a product from an amorphous material. Some processes produces finish products or articles into its usual form whereas others do not, and require further working to finish component to the desired shape and size. Castings need re-melting of scrap and defective ingots in cupola or in some other melting furnace and then pouring of the molten metal into sand or metallic moulds to obtain the castings. Thus the intricate shapes can be manufactured. Typical examples of the products that are produced by casting process are machine beds, automobile engines, carburetors, flywheels etc. The parts produced through these processes may or may not require to under go further operations. Some of the important primary shaping processes is:

(1) Casting, (2) Powder metallurgy, (3) Plastic technology, (4) Gas cutting, (5) Bending and (6) Forging.

1.7.2. Secondary or Machining Processes

As large number of components require further processing after the primary processes. These components are subjected to one or more number of machining operations in machine shops, to obtain the desired shape and dimensional accuracy on flat and cylindrical jobs. Thus, the jobs undergoing these operations are the roughly finished products received through primary shaping processes. The process of removing the undesired or unwanted material from the workpiece or job or component to produce a required shape using a cutting tool is known as machining. This can be done by a manual process or by using a machine called machine tool (traditional machines namely lathe, milling machine, drilling, shaper, planner, slotter). In many cases these operations are performed on rods, bars and flat surfaces in machine shops. These secondary processes are mainly required for achieving dimensional accuracy and a very high degree of surface finish. The secondary processes require the use of one or more machine tools, various single or multi-point cutting tools (cutters), job holding devices, marking and measuring instruments, testing devices and gauges etc. for getting desired dimensional control and required degree of surface finish on the workpieces. The example of parts produced by machining processes includes hand tools machine tools instruments, automobile parts, nuts, bolts and gears etc. Lot of material is wasted as scrap in the secondary or machining process. Some of the common secondary or machining processes are—

(1) Turning, (2) Threading, (3) Knurling, (4) Milling, (5) Drilling, (6) Boring, (7) Planning, (8) Shaping, (9) Slotting, (10) Sawing, (11) Broaching, (12) Hobbing, (13) Grinding, (14) Gear cutting, (15) Thread cutting and (16) Unconventional machining processes namely machining with Numerical Control (NC) machines tools or Computer Numerical Control (CNC) machines tools using ECM, LBM, AJM, USM setups etc.

1.7.3 Metal Forming Processes

Forming processes encompasses a wide variety of techniques, which make use of suitable force, pressure or stresses, like compression, tension and shear or their combination to cause a permanent deformation of the raw material to impart required shape. These processes are also known as mechanical working processes and are mainly classified into two major categories i.e., hot working processes and cold working processes. In these processes, no material is removed; however it is deformed and displaced using suitable stresses like compression, tension, and shear or combined stresses to cause plastic deformation of the materials to produce required shapes. Such processes lead to production of directly usable articles which include kitchen utensils, rods, wires, rails, cold drink bottle caps, collapsible tubes etc. Some of the important metal forming processes are:

Hot working Processes

(1) Forging, (2) Rolling, (3) Hot spinning, (4) Extrusion, (5) Hot drawing and (6) Hot spinning.

Cold working processes

(1) Cold forging, (2) Cold rolling, (3) Cold heading, (4) Cold drawing, (5) Wire drawing, (6) Stretch forming, (7) Sheet metal working processes such as piercing, punching, lancing, notching, coining, squeezing, deep drawing, bending etc.

1.7.4 Joining Processes

Many products observed in day-to-day life, are commonly made by putting many parts together may be in subassembly. For example, the ball pen consists of a body, refill, barrel, cap, and refill operating mechanism. All these parts are put together to form the product as a pen. More than 800 parts are put together to make various subassemblies and final assembly of car or aero-plane. A complete machine tool may also require to assemble more than 100 parts in various sub assemble or final assembly. The process of putting the parts together to form the product, which performs the desired function, is called assembly. An assemblage of parts may require some parts to be joined together using various joining processes. But assembly should not be confused with the joining process. Most of the products cannot be manufactured as single unit they are manufactured as different components using one or more of the above manufacturing processes, and these components are assembled to get the desired product. Joining processes are widely used in fabrication and assembly work. In these process two or more pieces of metal parts are joined together to produce desired shape and size of the product. The joining processes are carried out by fusing, pressing, rubbing, riveting, screwing or any other means of assembling. These processes are used for assembling metal parts and in general fabrication work. Such requirements usually occur when several pieces are to be joined together to fabricate a desired structure of products. These processes are used developing steam or water-tight joints. Temporary, semi-permanent or permanent type of fastening to make a good joint is generally created by these processes. Temporary joining of components can be achieved by use of nuts, screws and bolts. Adhesives are also used to make temporary joints. Some of the important and common joining processes are:

(1) Welding (plastic or fusion), (2) Brazing, (3) Soldering, (4) Riveting, (5) Screwing, (6) Press fitting, (7) Sintering, (8) Adhesive bonding, (9) Shrink fitting, (10) Explosive welding, (11) Diffusion welding, (12) Keys and cotters joints, (13) Coupling and (14) Nut and bolt joints.

1.7.5 Surface Finishing Processes

Surface finishing processes are utilized for imparting intended surface finish on the surface of a job. By imparting a surface finishing process, dimension of part is not changed functionally;

either a very negligible amount of material is removed from the certain material is added to the surface of the job. These processes should not be misunderstood as metal removing processes in any case as they are primarily intended to provide a good surface finish or a decorative or protective coating on to the metal surface. Surface cleaning process also called as a surface finishing process. Some of the commonly used surface finishing processes are:

(1) Honing, (2) Lapping, (3) Super finishing, (4) Belt grinding, (5) Polishing, (6) Tumbling, (7) Organic finishes, (8) Sanding, (9) deburring, (10) Electroplating, (11) Buffing, (12) Metal spraying, (13) Painting, (14) Inorganic coating, (15) Anodizing, (16) Sheradising, (17) Parkerizing, (18) Galvanizing, (19) Plastic coating, (20) Metallic coating, (21) Anodizing and (22) Sand blasting.

1.7.6 Processes Effecting Change in Properties

Processes effecting change in properties are generally employed to provide certain specific properties to the metal work pieces for making them suitable for particular operations or use. Some important material properties like hardening, softening and grain refinement are needed to jobs and hence are imparted by heat treatment. Heat treatments affect the physical properties and also make a marked change in the internal structure of the metal. Similarly the metal forming processes effect on the physical properties of work pieces Similarly shot peening process, imparts fatigue resistance to work pieces. A few such commonly used processes are given as under:

(1) Annealing, (2) Normalising, (3) Hardening, (4) Case hardening, (5) Flame hardening, (6) Tempering, (7) Shot peeing, (8) Grain refining and (9) Age hardening.

In addition, some allied manufacturing activities are also required to produce the finished product such as measurement and assembly.

1.8. PRODUCT SIMPLIFICATION AND STANDARDISATION

The technique of simplification and standardization of product is closely inter-related that leads to higher efficiency in production, better quality and reduced production cost. Simplification is a process of determining limited number of grades, types and sizes of a components or products or parts in order to achieve better quality control, minimize waste, simplify production and, thus, reduce cost of production. By eliminating unnecessary varieties, sizes and designs, simplification leads to manufacture identical components or products for interchangeability and maintenance purposes of assembly of parts. Standardization is the important step towards interchangeable manufacture, increased output and higher economy. The technique of standardization comprises of determining optimal manufacturing processes, identifying the best possible engineering material, and allied techniques for the manufacture of a product and adhering to them very strictly so long as the better standards for all these are not identified. Thus definite standards are set up for a specified product with respect to its quality, required equipment, machinery, labor, material, process of manufacture and the cost of production. The identified standard with time for a specified product should never be taken as final for ever because improvement is always possible. It must accommodate the outcome of all the new researches in the manufacturing areas in order to keep pace with increasing global competition. Improvements over the existing standards in all respects should always be welcomed. The different standards prevailing in different industries may be of the types of managerial, design, manufacturing and technical needs. Managerial standards are applicable to administrative functions within industry. These include the company policy, accounting procedures, personnel policies, performance evaluation, control of expenditures, safety aspects,

security procedures and regulations, etc. where as design, manufacturing and technical standards are needed for manufacturing concepts of the industry. These include design and manufacturing techniques, practices, materials and parts, supplies, methods of testing, drafting method, abbreviations and symbols, specifications and nomenclature, etc.

1.9 INSPECTION AND QUALITY CONTROL

A product is manufactured to perform desired functions. It must have a specified dimension such as length, width, height, diameter and surface smoothness to perform or accomplish its intended function. It means that each product requires a defined size, shape and other characteristics as per the design specifications. For manufacturing the product to the specified size, the dimensions should be measured and checked during and after the manufacturing process. It involves measuring the size, smoothness and other features, in addition to their checking. These activities are called measurement and inspection respectively.

In the era of globalization, every industry must pay sufficient attention towards maintaining quality because it is another important requirement or function of a production unit. If a manufacturing concern wants to survive for longer time and to maintain its reputation among the users, it should under all condition apply enough efforts not only to keep up the standard of quality of its products once established but to improve upon the same from time to time. For this, every manufacturing concern must maintain a full-fledged inspection and quality control department which inspects the product at different stages of its production. Vigilant inspection of raw materials and products depends upon the entire process of standardization. The production unit of manufacturing concern must produce identical products. However a minor variation may be allowed to a predetermined amount in their finished dimensions of the products. The two extremities of dimensions of the product are called limits. All the parts of which the finished dimensions lie within these limits are acceptable parts. This facilitates easy and quicker production, easy inspection, requires less skill on the part of worker and accommodates a slight inaccuracy in the machine as well, resulting in an over all reduction in the production cost of the part.

1.10 MECHANIZATION AND AUTOMATION

Mechanization means something is done or operated by machinery and not by hand. Mechanization of the manufacturing means is milestone oriented trend towards minimizing the human efforts to the extent of its possibility, by adopting mechanical and electrical means or methods for automating the different manufacturing processes. Such a trend may be in the area of automating and mechanizing the processes of material handling, loading and unloading of components, actual operations performed on the job or transportation, etc. But, no feedback is provided by the process, operation or machinery. Extension of mechanization of the production process is termed as automation and it is controlled by a closed loop system in which feedback is provided by the sensors. It controls the operations of different machines automatically. The automatic control may be applied for some operations or for all the operations of a machine or group of machines. Accordingly the machine will be known as semi-automatic or fully automatic. The term was identified shortly after the World War II at the Ford Motor Company to describe the automatic handling of materials and parts between the process operations. The word ‘automation’ is derived from the Greek word automatos meaning self-acting. Automation can also be defined as the process of following a predetermined sequence of operations with little or no human intervention, using specialized equipment and devices that

perform and control the manufacturing process. Automation is a word that has many meanings in the industry today. Automatic machines of all kinds existed long before the term automation was conceived. But, it should be noted that all automatic machines do not come under the category of automation. Automation is a technology concerned with the application mechanical, electronic, and computer based systems to operate and control production.

Every machine should involve some automation, may be to a lesser degree or to a higher extent to which is mainly governed by economic considerations. Automation means a system in which many or all of the processes in the production, movement, and inspection of parts and material are performed under control by the self-operating devices called controllers. This implies that the essential elements of automation comprise of mechanization, sensing, feedback, and control devices. The reasons why one should go for automation are:

1. Increased productivity
2. Reduced cost of labor and dependence on labor shortages
3. Improved quality
4. Reduced in-process inventory
5. Reduced manufacturing time
6. Reduced dependence on operator skills
7. Increased safety or reduced risk of humans.

Automation can be classified into three categories, viz.

1. Fixed automation
2. Programmable automation
3. Flexible automation.

1.10.1 Fixed Automation

It is also known as hard automation which is utilized to produce a standardized product such as gears, nuts and bolts, etc. Even though the operating conditions can be changed, fixed automation is used for very large quantity production of one or few marginally different components. Highly specialized tools, devices, equipment, special purpose machine tools, are utilized to produce a product or a component of a product very efficiently and at high production rates with as low unit costs as possible relative to other alternative methods of manufacturing.

1.10.2 Programmable Automation

In programmable automation, one can change the design of the product or even change the product by changing the program. Such technique is highly useful for the low quantity production of large number of different components. The equipments used for the manufacturing are designed to be flexible or programmable. The production normally carried out in batches.

1.10.3 Flexible Automation

There is a third category possible between fixed automation and programmable automation that is called flexible automation using Computer Aided Design (CAD) and Computer Aided Manufacturing (CAD/CAM) activities. This is also called as flexible manufacturing system (FMS). It allows producing different products on the same equipment in any order or mix. One important example of programmable automation, in discrete manufacturing, is numerical control. Robot is another example of programmable automation. Robot being integral part of

FMS and Computer Integrated Manufacturing (CIM) system can do a large number of manufacturing tasks for replacing the human labor.

In the present globalized manufacturing scenario, the advancements of hardware and software concepts using the mechatronics for fast mechanization and automation of manufacturing processes have become essential to be incorporated in the manufacturing areas.

1.11 COMPUTER AIDED MANUFACTURING (CAM)

The computer aided manufacturing implies manufacturing itself, aided or controlled by computers. In a wider sense, it denotes all the activities in the manufacturing environment like use of computers in inventory control, project management, material requirement planning, data acquisition, testing and quality control. Improved reliability in view of the better manufacturing methods and controls at the manufacturing stage, the products thus manufactured as well as of the manufacturing system would be highly reliable. Since most of the components of a CAM system would include integrated diagnostics and monitoring facilities, they would require less maintenance compared to the conventional manufacturing methods. Because of the Computer Numerical Control (CNC) machines used in production and the part programs being made by the stored geometry from the design stage, the scrap level would be reduced to the minimum possible and almost no rework would be necessary. Since all the information and controlling functions are attempted with the help of the computer, a better management control on the manufacturing activity is possible. All the above advantages when properly translated, would mean a lower total cost and consequently, higher final earnings. Therefore any manufacturing activity in a production unit (job shop production or mass scale manufacture) can get the benefits of Computer Aided Manufacturing. However, better results can be obtained when the design and manufacturing activities are properly integrated. Also, when there is a large variety of products or minor changes required in the existing production programme, CAM can easily manage the necessary changes or alterations. Following are the main advantages of using CAM.

1. Greater design freedom

Any changes that are required in design can be incorporated at any design stage without worrying about any delays, since there would hardly be any in an integrated CAM environment.

2. Increased productivity

In view of the fact that the total manufacturing activity is completely organized through the computer, it would be possible to increase the productivity of the plant.

3. Greater operating flexibility

CAM enhances the flexibility in manufacturing methods and changing of product lines.

4. Shorter lead time

Lead times in manufacturing would be greatly reduced.

The integration of CAD and CAM systems is called Computer Integrated Manufacturing (CIM) system. The role of computer in manufacturing may be in two major groups namely computer monitoring and control of the manufacturing process and manufacturing support applications, which deal essentially with the preparations for act of manufacturing and post manufacture operations. Computers are used in controlling machine tools and other material handling equipments.

1.12 KINDS OF PRODUCTION SYSTEMS

The choice of production type dictates the machine requirements, organizational system to a large extent, layout planning and inventory subsystems. Three main types of production are job, batch and flow or process production. The simplest way is to classify based on production and processes by lot size, namely single unit production, small lot production, moderate lot production, large lot production, and continuous production. The second classification comprises three categories, namely small size production of a large variety of products, medium-scale production of a limited range of products, and a large-scale production of a small variety of products. Obviously, this method is related to the number of product types and production lot sizes, and is an effective means of analyzing modern production management. The third classification is related to the size of the production system expressed through the number of employees or the amount of fixed assets involved, namely small production unit employing less than 30 employees, medium-small having 30 to 300 employees, medium with 301 to 2,000 employees and large with 2001 to 15,000 employees, and a giant corporation employing more than 15,000 employees

Job shop production deals the manufacture of very small lots, often of single jobs. This may be required in special situations for the purpose of proving a design, making prototypes, in tool making or for special purpose applications. In view of the very small lot, no special purpose machines or tooling can be economically justified. Hence, the manufacturing has to be carried on with the general purpose machines and tooling, which is a very lengthy and often an error prone process.

1.13 MANUFACTURING SYSTEM

Manufacturing basically implies making of goods or articles and providing services to meet the needs of mankind. It creates value by useful application of physical and mental-labor in the process. It is a chain of interrelated activities of production process and other support services activities of an manufacturing environment such as order processing, product design, design and manufacturing of tools, die, mould, jigs, fixtures and gauges, selection of material, planning, managing and maintaining control of the processes, production, and reliable quality of processed product in a systematic and sequential manner with proper coordination, cooperation and integration of the whole manufacturing system that will lead to economical production and effective marketing of proposed product in the minimum possible time. It is, therefore, evident that manufacturing today is not a one man activity as it was in the initial stages, wherein all the physical and mental inputs were applied by a single craftsman. These days it has become totally a team work which consists of several components interacting together in a dynamic manner. This entire domain of manufacturing is known as Manufacturing System, which takes the required inputs and delivers the products for the customer. It is, therefore, evident that manufacturing today is not a one man activity as it was in the preliminary stages, wherein all the physical and mental inputs were provided by a single workman. Today it is a team work which consists of several components interacting together in a dynamic manner to provide the required physical and mental inputs at appropriate stages to impart desired results. This entire domain of manufacturing is known as Manufacturing System, which takes the required inputs and delivers the products for the customer.

Manufacturing system requires a large number of activities, few independent and rests mostly interrelated. The manufacturing activities in a manufacturing system jointly contribute

towards economic and qualitatively acceptable production of desired articles in minimum possible time. As per the need of the customer, the products are identified and their demands are determined roughly for market forecast by considering present and future competition. Products that may render the desired service over its expected life satisfactorily as per requirement of customers are identified in terms of their demand, conceived and developed for securing orders by the sales department. Once the product design activity is over and the design finalized from all angles, functional, aesthetic, material selection, safety, economy, etc., it is followed by preparation of production drawings of the product assembly and its components including a bill of materials. This is the stage where a make or buy decision has to be taken in order to decide as to which components are to be bought from outside and which are to be manufactured within the concern. It is followed by process planning i.e. selection of the best process and an its parameters, design of jigs, fixtures and dies, selection of tooling, programming of tool path as per need, for the components to be produced in-house. An important activity in process planning within the organization is also to involve latest research and development findings, through which the old processes are improved and new one's are developed in order to ensure better quality and economic production. The interaction of different manufacturing activities in a manufacturing system can also be further enhanced by the use of computer and hence leading CIM. The real manufacturing or production activity is carried out on the shop. The layout of the shop floor has a significant influence on the tools required to be coordinated in order to an economical and high quality production of various components. It should be such that it ensures timely movement of raw materials, dies moulds, jigs and fixtures and finished components, adequate safety to men, material and machinery, enables timely inspection and quality control and minimizes handling time for material and parts, etc. During actual manufacturing a lot of different activities are called management function. Various engineers play an important role in the organizational function of a manufacturing concern. They are required to ensure proper movement of the material, tools and parts as per their specialized jobs in industry.

1.14 PRODUCT DEVELOPMENT

A product development has to go through the following concepts of product engineering which are given as under.

Product functions

1. Product specifications
2. Conceptual design
3. Ergonomics and aesthetics
4. Standards
5. Detailed design
6. Prototype development
7. Testing
8. Simulation
9. Design for manufacture
10. Design for assembly
11. Drafting.

Now let us consider the manufacturing environment of a given product. How does the product idea originate. Market forces determine the need for a product. Expertise on the part

of the company estimates the likely demand and probable profitability and decides on the best mode of designing and manufacturing the desired product.

Traditionally, after the design of the product, the part prints are released for production. The production engineering section first considers the feasibility of production of the product. Having ascertained its feasibility, process planning is done so that the product can be manufactured at the lowest possible cost. Any redesign that is needed for improving the producibility of the product without compromising on its functionality would have to be done at this stage. Having decided on the process plan for manufacture, the necessary actions are undertaken for its implementation. These are making of the tooling required, acquiring of new equipment or tools, procurement of the raw materials, releasing of the detailed operational instructions to the shop floor, etc. The conventional methods of manufacturing are generally inefficient and dependent on operator skills. These methods consume more time, have high costs, and give poor accuracy.

Product design is an activity which needs to be well organized and take into account all influences that are likely to be responsible for the success of the product under development. A product here means a single component which is functional in itself like a wrench or an assembly of a large number of components all of which will contribute to the functioning of the part such as an automobile engine. The complexity of the design process certainly increases with the number and diversity of components present in the final part. Since there are such a large number of influencing factors, it is impossible to specify a design procedure for each component. Here we are interested in developing some common guidelines and steps that are needed to proceed for a successful product design and manufacture.

From the above discussion it can inferred that products can be manufactured by more than one processes. Therefore several alternatives for manufacturing products are available. The selection of a suitable process is depended upon the factors including volume of production, properties of the components, technical viability of process, economy involved and desired quality. Based upon the volume of product the manufacturing activity can be identified in terms of job shop production, batch production and mass production

1.15 COMPUTERS IN MANUFACTURING INDUSTRIES

Factors governing increased productivity, more accuracy, greater flexibility of shapes, and reduced manufacturing costs are forcing the manufacturing concerns to use computers in design, manufacturing and other allied functions of industrial activities. With an increase in the need for quality manufacturing along with the factors such as short lead time and short product lives and increasing consumer awareness as regards the quality of the product, it is becoming increasingly important for the manufacturers to initiate steps to achieve all these. The developments in microelectronics in the recent past have made higher computational ability available at a low cost. Therefore, it becomes imperative that manufacturing takes advantage of the availability of low cost and also using yet more powerful computers. Computers have been in use in manufacturing industries since 1960. Initially they were in use only in supportive functions such as inventory control purchase accounting, etc. In to day's time, computer applications have progressed considerably in all areas of design and manufacturing involving CAD and CAM. This however needs to be emphasized that all the benefits of CAD and CAM can be achieved only if these two important functions are effectively interfaced. This interfacing is known as CAD/CAM. It involves the flow of information in both the directions. With the result the parts and assemblies are designed keeping in view the limitations and

capabilities of the processes and materials. Consequently, newer and superior products can be produced more quickly and at lower costs.

Today, computers are not only used in manufacturing but they play also an important role in all manufacturing related activities such as business or financial management, factory level production management, CIM technologies, CAD, feature and solid modelling, and CAM, manufacturing information, manufacturing system. The important sub-activities of industrial environment have been identified to support with the use of computer in the manufacturing industries. These are given as under:

1. Business or Financial Management

1. Costing
2. Sales and Marketing
3. Purchase Order Control
4. Vendors
5. Subcontracting
6. Personnel.

2. Factory Level Production management

1. Planning
2. Production Management
3. Manufacturing production scheduling (MPS)
4. Material requirement planning (MRP)
5. Just in time (JIT)
6. Bill of Materials
7. Capacity Planning
8. Inventory Control.

3. CIM Technologies

1. Computer Networks
2. System Design and Analysis
3. Distributed Processing
4. Database Management Manufacturing
5. Modelling and Simulation
6. Expert Systems
7. Quality Engineering.

4. Computer Aided Design (CAD)

This area is also known Feature and Solid Modelling

1. Variational and Parametric
2. Modelling
3. Computer Graphics
4. Graphic Standards

5. Inter-graphics exchange specification (IGES)
6. Data exchange file (DXF)
7. Manufacturing Robot Programming
8. Design Analyses Tools
9. Programming
10. Finite element modelling (FEM)
11. Finite element analysis (FEA)
12. Simulation
13. Mechanisms
14. Test and Analysis
15. Design Tools Mechanical
16. Hydraulic, Electronics, etc.

5. Computer Aided Manufacturing (CAM)

This involves activities related to manufacturing information and manufacturing system which are given as under—

Manufacturing Information

1. Generation
2. Process Planning
3. Production Planning
4. Computer numerical control (CNC) part Programming
5. Robot Programming
6. Coordinate measuring machine (CMM) Programming.

Manufacturing System

1. Production Activity
2. Machining
3. Assembly
4. Material Handling
5. Storage
6. Production Control
7. Loading
8. Scheduling
9. Balancing
10. Capacity Planning
11. Quality Control.

One of the most important components for getting various benefits associated with computer applications in manufacturing is the common databases associated with all aspects of manufacturing. In fact, all the modules in the CAM would actually be sharing the database created in any module. Any module would be able to modify the data as required for that

particular application. This approach reduces the work involved in maintaining the product database and at the same time includes the latest modifications for any aspect related to manufacturing. In contrast to the common database approach, it is possible that sometimes individual modules in the production aspects may be taken from different vendors. In this case care need to be taken that information is properly transmitted between the modules and the data updating in all the modules takes place properly and at the right time. Some of above mentioned manufacturing activities are controlled by computers. These activities are commonly identified using the following terms.

1. Computer Aided Design (CAD)
2. Computer Aided Engineering (CAE)
3. Computer Aided Design And Drafting (CADD)
4. Computer Aided Process Planning (CAPP)
5. Computer Aided Tool Design (CATD)
6. Computer Aided Manufacturing (CAM)
7. Computer Aided Numerical Control (NC) Part Programming
8. Computer Aided Scheduling
9. Computer Aided Material Requirement Planning, etc.
10. Flexible Manufacturing System (FMS)
11. Group Technology (GT)
12. Computer aided Testing (CAT).

1.16 QUESTIONS

1. How do you classify the manufacturing processes?

2. Distinguish between 'primary' and 'secondary' processes?

3. Discuss primary shaping processes. Give also a brief account of the primary shaping processes.

4. Explain the secondary or machining processes. Give also a brief account of these processes.

5. Describe and name the types of joining processes, surface finishing operations and the processes employed for changing the properties of manufactured components.

6. Write a short note on assembly process.

7. Write short notes on:

(a) Simplification, (b) Standardization, (c) Inspection and quality control, (d) Interchangeability, (e) Mechanization, (f) Automation, (g) Mechatronics.

8. What do you understand from the terms Manufacturing, Process plan, Maintenance?

9. Explain the term 'Manufacturing System'. What all it encompasses and how an integrated approach is made for making an economical and competitive product? Describe how the use of computers helps in increasing manufacturing efficiency.

10. Explain the terms CAD, CAM, NC, CAD/CAM, MRP, FMS and CIM?

11. Write a short note on Group Technology?

12. Explain the influence exerted by the computers on the manufacturing scene?

13. Briefly explain the conventional process of the product cycle in the conventional manufacturing environment.

14. What are the functions that get benefited by the use of computers in design and manufacturing functions?

15. Briefly explain the various automation aspects used in manufacturing activities.

16. Write down the advantages which can be gained by the adoption of CAD?

17. Describe the advantages which can be gained by the adoption of CAM?

18. Write down the advantages which can be gained by the adoption of FMS?

19. Write down the advantages which can be gained by the adoption of manufacturing production scheduling (MPS)?

20. Write down the advantages which can be gained by the adoption of Material Requirement Planning (MRP)?

21. Explain the main advantages which can be gained by the adoption of CIM?

2
CHAPTER

PLANT AND SHOP LAYOUT

2.1 INTRODUCTION

In a manufacturing organization, a job to be manufactured spends most of the time in moving and waiting. For reduction of this moving and waiting time of jobs/parts, it is necessary to have proper layout and proper scheduling procedure. Plant layout specifies the position of the overall arrangement of the various facilities such as equipments, material, manpower, materials handling, service facilities, and passage required to facilitate efficient operation of production system of the plant within the area of the site selected previously. Shop layout in manufacturing plant also forms an integral part of factory planning or plant layout. Plant layout begins with the design the position of the factory building and goes up to the location and movement of a work table of the machine. All the manufacturing facilities such as equipments, raw materials, machinery, tools, fixtures, workers, etc. are given a proper place in each shop of the manufacturing plant. Plant layout of an industrial organization plays an important role in scientific management and is defined as :

"Plant layout is such a systematic and efficient functional arrangement of various departments, machines, tools, equipment and other supports services of an industrial organization that will facilitate the smooth processing of the proposed or undertaken product in the most effective, most efficient and most economical manner in the minimum possible time"

Plant layout of an industrial organization comprises of all the aspects connected with the industrial enterprise, viz., grounds, buildings, machinery, equipment, departments, methods of manufacturing, factory services, material handling, flow of production, working conditions, hygiene, labor and shipment of goods, etc. It does not necessarily mean planning a new enterprise only. However, it also involves minor improvements, here and there, in the existing layout, expansion of the exiting plant, re-layout of the existing plant and layout of a new proposed plant. In a best possible plant layout, material handling and transportation is minimized and efficiently controlled. Bottlenecks and points of congestions are eliminated so that the raw material and semi-finished goods move fast from one work station to another. Work stations are designed suitably to facilitate the smooth processing of the proposed or undertaken product in the most effective, most efficient and most economical manner in the minimum possible time. Optimal spaces are allocated to production centers and service centers. The primary goal of plant layout is to maximize profits by setting up the best possible arrangements of all plant facilities to the maximum advantage of reducing the cost of production of the proposed product.

2.2. OBJECTIVES OF GOOD PLANT LAYOUT

Good plant layout comprises of best possible arrangement of the buildings, men, machine and materials for processing a under taken product. The main objectives of a good plant layout involves minimum material movement, smooth flow of the product in the plant, full utilization of the space of the plant, provide adequate safety and satisfaction to the plant workers, evolve sufficient flexibility in the arrangement of the above factors so as to suit the minor future changes, if any and facilitates an effective supervision. It helps to integrate all the above factors in such a way that the best compromise and coordination among them is achieved. The movements of workers and manufacturing staffs within the plant are minimized. Waiting time of the semi-finished and finished products should be reduced to the minimum. Working conditions as far as possible should be safer and better for the satisfaction of the workers. There should be an increased flexibility for changes in product design and for future expansion. There should be full utilization of whole space of the shop and plant layout. The work methods and reduced production cycle times should be improved and the plant maintenance must be simpler. There should be increased productivity and better product quality with reduced capital cost. A good layout facilitates materials to move through the plant at the desired speed with the minimum possible cost.

2.3. IMPORTANT FACTORS FOR INSTALLATION OF A PLANT

The important factors while planning for installation of plant include availability of space, power, water, raw material, good climatic conditions, good means of communication, ancillaries, low local taxes and similar other economic considerations, marketing facilities for the planned product, space for process disposal and skilled and unskilled labor locally. One has to keep in mind the possibilities of utilization and sale of the process wastes and by-products of the planned industry. Decision of manufacturing new product, financial and other aids, facilities for expansion presence of related industries, local by laws and securities, hospitality are also important factors which one must keep in mind for location of an enterprise. After finalizing the size and location of the plant, the next step is to design the inner layout of the plant to plan out the sequence of different shops and their locations accordingly to specifications of material and product, manufacturing processes, type of production, material handling facilities, system and facilities for storing, inter-dependability of one shop over the other, links among various shops, service facilities and lighting and ventilation. Next, the internal arrangement of the above mentioned infracturctral facilities of different shops are identified. This identification is termed as shop layout. The main factors namely size and type of equipment, number of machines to be installed, floor area required for working on each machine, power requirements for the machines, requirements of factory services, sequence of operations to be followed, visibility to all the machines for proper supervision and control, type of drive used, safe working conditions, provision of stores within the shop, i.e. for tools, instruments, finished parts and consumable materials, etc. affects the layout of the plant. A good plant layout should meet the following basic requirement:

1. Integration of manufacturing centre facilities in terms of man, machine and material.
2. Movements of production personnel and material handling should be minimized.
3. Smooth and continuous flow of production or manufacturing work with least possible bottlenecks and congestion points.
4. Floor space utilization should be optimum as for as possible.

5. Working place should be free from pollution and safe working conditions should prevail in each shop of the plant.
6. The handling of raw material, semi finished and finished product should be should be tackled optimally and effectively
7. Plant layout and shop layouts must be flexible to facilitate changes in production requirements
8. There should be better working environment in term of proper light, ventilation and other amenities such as drinking water and toilets for welfare for the manufacturing personnel

2.4. MERITS OF A GOOD PLANT LAYOUT

The main advantages of a good plant layout involve effectively and economical utilization of entire floor space of the plant, increased rate of production, reduced men and machine hours per unit of production, reduced material handling, minimal production delays, effective utilization of men, machinery, material and other factory support services, reduced overall production time, elimination of large amount of paper work, significant reduction in the indirect expenses, considerable reduction in inventory work for material, promote effective supervision, facilitate easy flow of men, tools and material, promote flexibility in arrangement to suit the future changes, promotes better planning and effective control, facilitates better and easier maintenance of plant and machinery, provides safer and healthier working conditions thereby improving the morale of the workmen, provides the material as well as psychological satisfaction to the workers and enhance overall efficiency of the plant. The major merits of a good plant layout are given as under:

1. Reduced men and machine hours per unit of production,
2. Effectively and economical utilization of entire floor space of the plant,
3. Work flow is smooth and continuous
4. Work in process inventory is less
5. Production control is better
6. Manufacturing time is less
7. Relatively less floor area is required
8. Material handling is less.

2.5. TYPES OF LAYOUTS

The fulfilling the objectives of a good layout as per yearly product requirement and product types, the layouts are classified into four major categories namely fixed or position layout, line or product layout, process or functional layout and combination or group layout. Each kind of layouts is explained with respective merit, demerits and application as under.

2.5.1 Fixed or Position Layout

Fixed or position layout is also known as project layout. A typical fixed layout is shown in Fig. 2.1. In this type of layout the major part of an assembly or material remains at a fixed position. All its accessories, auxiliary material, machinery, equipment needed, tools required and the labor are brought to the fixed site to work. Thus, the product by virtue of its bulk

or weight remains at one location. Therefore the location of the major assembly, semi assembly component and material is not disturbed till the product is ready for dispatch. This layout is suitable when one or a few pieces of an item are to be manufactured and material forming or treating operation requires only tools or simple machines. This layout is highly preferable when the cost of moving the major piece of material is high and the responsibility of product quality by one skilled workman or group of skilled workers is expected. This type of layout is mainly adopted for extremely large items manufactured in very small quantity such as ships, aero planes, boilers, reactors etc. It main merit of this layout is the minimum movement of men, material, and tooling during manufacturing process. This layout is high flexible as the type of product and the related processes can be easily changed without any change in the layout. The merit and demerit of this type of layout is given as under.

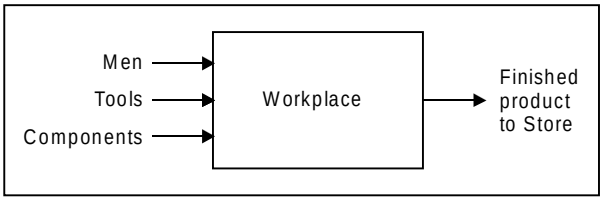


Fig. 2.1 Typical project layout

Merits

Its main merits are—

1. Layout is highly flexible for varieties of products having intermittent demand as the type of product and the related processes can be easily altered without any change in the layout.
2. There is a minimum movement of men, material, and tooling during manufacturing process.
3. The material is drastically reduced.
4. Highly skilled operators are required to complete the work at one point and responsibility for quality is fixed on one person or the assembly crew.
5. Every personnel of manufacturing team is responsible for quality work for manufacturing the product.

Demerits

The major demerits of this layout are

1. The cost of equipment handling is very high.
2. Labors and equipments are difficult to utilize fully.
3. It is limited to large items only.

Applications

This type of layout is mostly adopted for extremely large items manufactured in very small quantity such as ships, aero planes, aircraft, locomotive, ship assembly shops, shipyards, boilers, reactors etc.

2.5.2. Process or Functional Layout

A typical process or functional layout is shown in Fig. 2.2. In this type of layout arrangements of similar machines, production facilities and manufacturing operations are grouped together

according to their functions. Machine tools of one kind are positioned together so that all the similar operations are performed always at the same place e.g. all the lathes may be grouped together for all kinds of turning and threading operations, all drilling machines in one area for carrying out drilling work, all tapping machines in one area for carrying out tapping work, all milling machines in one area for carrying out milling work all buffing and polishing machines at one place for carrying out surface finishing work, and so on. This type of layout is normally preferred for the industries involved in job order type of production and manufacturing and/or maintenance activities of non- repetitive type. This layout needs not to have to be changed every time of the product or component changes. Also the breakdown of any machine does not affect the production. This type of layout is highly suitable for batch production.

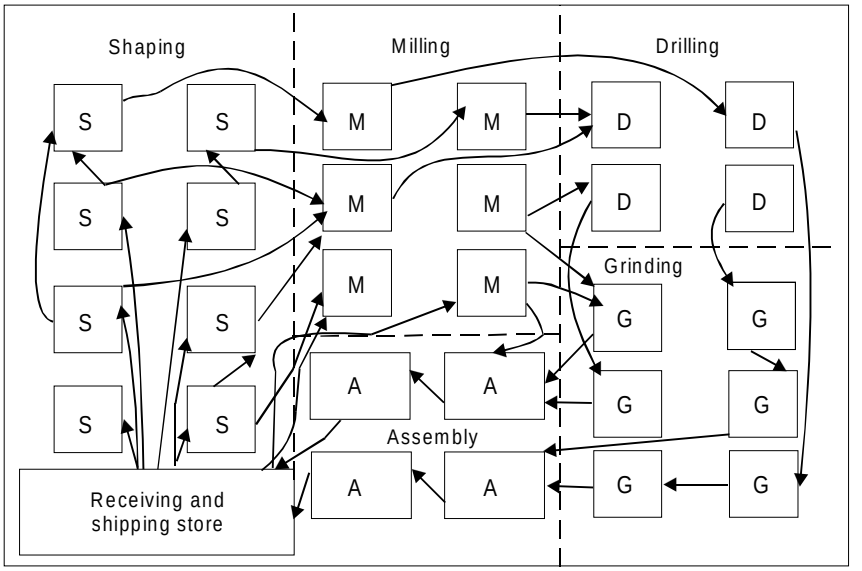


Fig. 2.2 Typical functional layout

Merits

The major merits of this layout are :

1. There exists a wide flexibility regarding allotment of work to equipment and workers.
2. There is a better utilization of the available equipment.
3. Comparatively less numbers of machines are needed in this layout and hence thus reducing capital investment.
4. There is an improved product quality, because the supervisors and workers attend to one type of machines and operations.
5. Varieties of jobs coming as different job orders thus make the work more interesting for the workers.
6. Workers in one section are not affected by the nature of the operations carried out in another section. For example, a lathe operator is not affected by the rays of the welding as the two sections are quite separate.

Demerits

The major demerits of this layout are :

1. This layout requires more space in comparison to line or product layout for the same amount of production.
2. Production control becomes relatively difficult in this layout.
3. Raw material has to travel more which increases material handling and the associated costs.
4. This layout requires more efficient co-ordination and inspections.
5. Increased material handling cost due to more movement of process raw material to various paths
6. More material in process remains in queue for further operations.
7. Requires large in-process inventory.
8. Completion of same product takes more time.

Application

1. This layout is used for batch or moderate production.
2. It specify path for group technology.

2.5.3. Line or Product Layout

A typical line or product layout is shown in Fig. 2.3. This layout implies that various operations on raw material are performed in a sequence and the machines are placed along the product flow line, i.e., machines are arranged in the sequence in which the raw material will be operated upon. In this type of layout all the machines are placed in a line according to the sequence of operations, i.e., each following machine or section is arranged to perform the next operation to that performed by its preceding machine or section. In this layout raw material starts from one end of production lines and moves from one machine to next along a sequential path. Line layout is advantages in the continuous- production system where the number of end products is small and the parts are highly standardized and interchangeable. It is suitable for products having steady demand. This layout may have operational sequence namely forging, turning, drilling, milling, grinding and inspection before the product is sent to the finished goods store for packing and shipment. This layout is used for mass production and ensures smooth flow of materials and reduced material handling. Breakdown of any machine in the line in this layout may result in even stoppage of production.

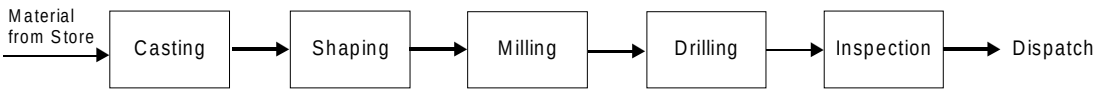


Fig. 2.3 Typical line layout

Merits

Its main merits are—

1. It involves smooth and continuous work flow.
2. It may require less skilled workers
3. It helps in reducing inventory.
4. Production time is reduced in this layout.

5. Better coordination, simple production planning and control are achieved in this layout.
6. For the same amount of production, less space requirements for this layout.
7. Overall processing time of product is very less.
8. This layout involves automatic material handling, lesser material movements and hence leads to minimum possible cost of manufacturing.

Demerits

The major demerits of this layout as compared with process layout are—

1. It is very difficult to increase production beyond the capacities of the production lines.
2. When single inspector has to look after many machines, inspection becomes difficult
3. This layout is very less flexible for product change.
4. The rate or pace rate of working depends upon the output rate of the slowest machine and hence leading to excessive idle time for other machines if the production line is not adequately balanced.
5. Machines being put up along the line, more machines of each type have to be installed for keeping a few as stand by, because if on machine in the line fails, it may lead to shut down of the complete production line. That is why the line or product layout involves heavy capital investments.

Applications

It is used in assembly work.

2.5.4. Combination Layout

Fig. 2.4 shows a typical combination type of layout for manufacturing different sizes of crank shafts. It is also known as group layout. A combination of process and product layouts combines the advantages of both types of layouts. Most of the manufacturing sections are arranged in process layout with manufacturing lines occurring here and there scattered wherever the conditions permit. These days, the most of manufacturing industries have adopted this kind of layout. In this type of layout, a set of machinery or equipment is grouped together in a section, and so on, so that each set or group of machines or equipment is used to perform similar operation s to produce a family of components. A combination layout is

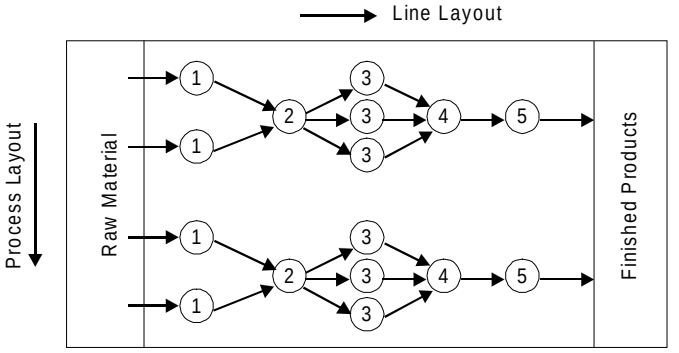


Fig. 2.4 Typical combination layout

possible where an item is being made in different types and sizes. In such cases, machinery and manufacturing equipments are arranged in a process layout but a group of number of similar machines is then arranged in a sequence to manufacture various types and sizes of products. In this layout, it is noted that, no matter the product varies in size and type, the sequence of operations remain same or similar. This layout is suitable when similar activities are performed together thereby avoiding wasteful time in changing from one unrelated activity to the next. It focuses on avoiding unnecessary duplication of an effort. It is preferable for storing and retrieving information changing related to recurring problems thereby reducing the search tin understanding information and eliminating the need to solve the problem again. It is also useful when a number of items are produced in same sequence but none of the items are to be produced in bulk and thus no item justifies for an individual and independent production line. There are some merits, demerits and application of this layout which are given as under :

Merits

The merits of this type of layout are:

1. Reduction in cost of machine set-up time and material handling of metals.
2. Elimination of excess work-in-process inventory which subsequently allows the reduction in lot size.
3. Simplification of production planning functions, etc.

Demerits

The major demerits of this layout are :

1. Change of the existing layout is time consuming and costly.
2. Inclusion of new components in the existing component requires thorough analysis.
3. Change of input component mix may likely to change complete layout structure.
4. Change of batch size may change number of machines.

Application

Manufacturing circular metal saws, hacksaw, wooden saw, files and crank shaft.

2.6 Comparison of Line or Product Layout and Process or Functional Layout

Comparison of line or product layout and process or functional layout is given in Table 2.1.

Table 2.1 Comparison of Line or Product Layout and Process or Functional Layout

S.No.	Line or Product Layout	Process or Functional Layout
1.	In line or product layout, similar machines are arranged according to the sequence of operations required for manufacturing the product.	In process or functional layout, similar machines are arranged in one location for manufacturing the product.
2.	It leads to transfer lines.	It leads to group technology.
3.	It is meant for mass production and extremely less job variety	It is meant for moderate production and more job variety
4.	Work flow is smooth in this layout	Work flow is not smooth in this layout
5.	Job movement is very less.	Job movement is comparatively more.
6.	Full automation in material handling is possible in this layout.	Automation in material handling is not effective in this layout.

7.	Machine utilization is poor in this layout.	Machinery utilization is better in this layout.
8.	Capital investment required is more in this layout.	Capital investment required is comparatively less in this layout.
9.	Inventory requirement is less.	Inventory requirement is comparatively more.
10.	Breakdown of one machine affects greatly in this layout.	Breakdown of one machine does not affect so much in this layout.
11.	Production planning and control is easy.	Production planning and control is comparatively difficult.
12.	Quality of product is not so good.	Quality of product quality is better
13.	Work flexibility is very less in this layout	Work flexibility is more in this layout
14.	Space required for same amount of production is less.	Space required for same amount of production is comparatively more.
15.	Time taken in completion of product is less.	Time taken in completion of product is more.
16.	Less skilled workers are required comparatively.	More skilled workers are required.
17.	Monotony in working is more because jobs are repetitive in nature in this layout.	Monotony in working is less because jobs are non-repetitive in this layout.
18.	It is used in mass production or assembly work.	It is used in job order production or maintenance work of non-repetitive type.

2.7 QUESTIONS

1. What do you understand by the term plant layout?

2. Name and explain different factors responsible for selection of the site for installation of a new plant layout.

3. What are the major objectives of plant layout?

4. What are the common advantages of a good plant layout?

5. Explain the various kinds of plant layout and the situations in which each type is used.

6. Compare process layout and product layout.

7. List out the equipments required for a sheet metal shop, carpentry shop, foundry shop, smithy and forging shop. Draw also the layouts of the above shops.

8. Prepare a layout for fitting shop and machine shop.

3
CHAPTER

INDUSTRIAL SAFETY

3.1 INTRODUCTION

With the advancement of scientific and technological developments in various areas of design and manufacturing, the danger of life of human being is increasing day by day. The importance of industrial safety was realized a century ago because every year millions of industrial or other accidents occur which result in either death or in temporary disablement or permanent disablement of the industrial employees. This results in large amount of loss or heavy damage in terms of property, wasted man-hours and machine hours. In order to avoid these accidents, employees should be aware of the basic safety principles and dangers which may exist in an industry. Accidents take place unexpectedly causing injury or loss to men, machines and materials in industry. Losses can be direct for examples; compensation to the worker, medical expenditures etc and indirect such as loss of time of the co-workers, demoralization to the group, training of new worker if the injured worker is to be replaced etc. The safety movement was initially started in 1912 with the First Cooperative Safety Congress and the organization of the National Safety Council of USA. From that time to today's time, remarkable advances have been made in reducing the rate and severity of industrial and other accidents. Because of safety first, all the industrial personnel must be trained enough about the safety aspects of man, machine and material and other infractstuctral facilities available there in for avoiding any kind of minor or major accidents. Safety is the first essentially requirement and every industrial personnel must learn the safety measures even before he starts working on a machine or on equipments. Safety is an attitude, a form of mind of the worker. If the attitude of a worker towards safety is good and he is safety conscious and he himself will develop the safe working habits. An industrial worker must think that working with other people in the shop is his business, to keep him as well as those working with him free from accidents is also a part of his attitude towards safety. Many injuries have resulted from a lack of appreciation of the fact that there are other industrial personnel working in the shop who might be taking care of safety aspects. A worker can easily learn to work safely. A good and safe industrial employee is one who is safety conscious, always adopting safe procedure. So safety is for everybody's concern. The safe working habits are always learned through practice. An industrial worker must practice safe working procedures at all time. Safety measures, safety rules and regulations, mechanical guards and devices, posters and lectures in an industry are very important, but they will never replace intelligent precautions taken by the worker in doing his work. Industry is always trying to reduce the number of accident in the shops and in plant

by safety measures. Every industrial personnel are required to contribute the efforts towards safety. For ensuring industrial safety, the first factory act in India was passed by the Governor General of India on 23rd Sept., 1948. It was further amended in 1950, 1951, 1954 and 1976, which came into force on 26th November, 1976.

3.2 SAFETY CONCEPTS

In all kinds of industries, each shop supervisor is generally assigned the responsibility of safety in his shop regarding the men, machines and materials. Every supervisor in each shop ensures to the top executives in respect of all kinds of the safety matters. He is supposed to incorporate all new safety measures needed in the shop from time to time. With the growth in the size of the industry and depending upon the hazardousness of industrial processes, a full fledged safety department should be created under the intensive supervision through a safety manager. The safety manager may be given a line position or staff position depending upon the working conditions in the industry. Sometimes the responsibility for safety rests on a safety committee formed by the top executives of the organization. A safety committee may consist of executives, supervisors, and shop floor workers. Thus the lower level employees get a channel of communication on safety matters direct to executive level. It is a matter of fact that those organizations which made safety committees had lower record of accidents than those without safety committees. Safety committees always motivate all the industrial employees for developing safety consciousness. It acts also as a policy making body on safety matters. To enhance the efficiency of the safety committee, some safety problem may be assigned to safety staff for identifying and implementing safety rules and publicizing them. Its members should be asked to go on the shop floor and watch what is being done there till date about the safety measures. It should be asked to report periodically as what improvements have been made and what more can be done for safety aspects in near future for avoiding any mis-happening in the plant. Safety committee often organizes safety programs to make industrial persons sufficiently alert for overall safety within the plant. A safety program tends to discover when, where and why accidents occur. It always aims at reducing accidents and the losses associated with them. It begins with the assumption that more work-connected accidents can be prevented. It does not have an end rather it is a continuous process to achieve adequate safety. It involves providing, safety equipments and special training to employees. It consists of support by top management, appointing a safety officer, engineering a safe plant, processes and operations, educating all industrial employees to work safely, studying and analyzing the accidents to prevent their occurrence in future, holding safety contests, safety weeks etc., and awarding incentives or special prizes to departments which enforces the safety rules and having least number of accidents.

A safety programme should always include engineering safety at the design and equipment installation stage, education of employees in safe practices, concerns the attitude of employees and management. It should motivate all the industrial employees in accident prevention and safety consciousness. It must provide all safety instructions and training essential for the employees to think, act and work safely so that the number of accidents can be minimized. Safety education must give knowledge about safe and unsafe mechanical conditions and personal practices. Safety training must involve induction and orientation of new recruits to safety rules and practices, explaining safety function, during their initial job training through efforts made by the first level supervisors. Formulating employee's safety committees, holding of employee's safety meeting, display of charts, posters, film etc. are very much essential in each industry for stressing the need to act safely. It educates employees to develop their

safety consciousness. An industrial worker will usually accept the use of a safety measure if he is convinced of its necessity. Therefore, suitable measures must be adopted to increase the awareness of a need for safety in the environment of work. Such measures are required in an industrial organization to develop safety consciousness among workers or other employees. There should be sufficient display of safety posters and films from time to time to remind industrial workers to particular hazards/accidents, providing simple and convenient safety devices, providing time to the worker for setting, removing and replacing any necessary safety devices. All industrial personnel should be asked from the first day to start working to adopt safety measures because an unskilled worker should be familiar fully to work safely. A safety committee should manage regular safety programmes that may hold safety competitions. Award and prizes are also to be given to the winners for imparting due respect and recognition to safe workers and create in employees a feeling of pride in safe work. It should elaborate on the safety theme until all the employees are safety conscious. It must hold regular safety meetings and stimulates the safety ideas in industrial workers for being more safety conscious. It must ask the shop supervisor to display all the safety aspects near the work centre. It should also mail safety information and sufficient literature pertaining to safety for reading at homes of all the industrial employees. It must welcome all safety suggestions. It must mark categorically all accident areas. It must conduct safety training lectures periodically for providing wide publicity to safety aspects for everything including men, machines and materials

3.3 PLANNING FOR INDUSTRIAL SAFETY

Mis-happening of a large number of fire hazards, accidents, industrial disasters etc., can be reduced to the minimum possible extent through careful safety planning within an industrial organization. All these unwanted events can be prevented by effective planning for safety. Safety consideration includes proper layout of buildings and equipment, such as providing adequate ventilation, sufficient working area to the operator, clear pathways for movement of materials and parts, provision for adequate personnel facilities- viz., canteens, lunch rooms, dispensary, fire fighting services, etc. Careful planning in advance for optimized and safe layout of design and manufacturing activities for industry ensures industrial safety in the manufacturing and inventory areas. Incorporating safety considerations well in time are helpful for the establishment of a new plant as well as an existing plant needing major alterations. Such considerations lead to adequate safety to men, machine and equipments, reduction in operational time and increase in production. Several codes and standards for industrial safety, health and hygiene, fire prevention, etc. have been prescribed by government and other safety agencies and they should be fully taken care of at the planning and implementation stages of a plant. A number of important features should be considered and suitably incorporated planning the layout of a new plant and its buildings for safety. Hoists and conveyors are commonly used in industries for raising, lowering and transporting loads for limited distances. A high degree of safety is needed while these equipments are in operation. During operations of these equipments, one should keep in mind the following important safety measures.

Material handling and its storage are very common functions in a plant. Material handling when performed manually the chances of injuries are greater. Therefore the following points should be taken care for carrying out such tasks. All material handling equipments such as conveyers, automotive guided vehicles, robots, cranes should carry proper guards for its gears and other dangerous moving parts to prevent access from these parts during operation. All

hoisting devices must be equipped with limit switches for preventing loads block from over traveling accidentally. Hoisting equipment especially cranes, should only be operated by properly trained personnel for avoiding all sorts of mishaps or accidents. While operating a crane, the operator should be entirely guided by standard signal and both operator and his signaler should be thoroughly trained. Proper protections against fire and explosion hazards are required when gasoline operated crains are being used. Where manual loading is done on conveyors which run along a vertical path, either partially or totally, safe load sign should be prominently displayed on all loading stations. Sufficient lighting, ventilation, drainage, escape ways and guarding should be provided for conveyors which run in pits, tunnels and similar other enclosures. Riding on a conveyor should always be prohibited. All the persons working on or around the conveyor must wear tight cloths and safety shoes. All rotating, reciprocating and projecting parts of machinery and equipments such as sprockets, gears, etc., should be adequately protected by proper guarding. An effective lubrication schedule should be worked out and implemented. All inspection should be carried out regularly and worn out parts, if any, should be replaced immediately.

The workers should be properly trained to adopt safe working habits and proper supervision should be done while these operations are being carried out manually. Industrial personnel and unskilled workers should be adequately trained for adopting safe working habits in the proper ways of lifting and setting down the objects. They should be told to be careful from pinches and shear points and to grasp the articles firmly when lifting or setting down. Objects which are wet or dirty or have slippery surfaces, such as greasy or oily and wet articles should be completely wiped off dry before handling them. The hands should also be kept free of oil and grease. For preventing hand injuries the handlers should be made to wear protective clothing like leather hand gloves, sleeves, etc. The worker handling materials should always wear foot in order to prevent foot injuries. If an object is to be lifted and carried to some distance it should be ensured that the pathway is not slippery and there are no obstructions on the passage or way. The unskilled industrial workers should be properly trained for keeping correct positions of their feet, positions of back and knees, holding the object close to the body while lifting and carrying, correct and firm grip, position of chin and application of body weight in lifting and setting down by hand. This will help to prevent muscle strains and back injuries. When a gang or team of workers is used to carry a heavy load form one place to another the supervisor should ensure the use of proper tools and direct the work himself to ensure proper synchronization in the lifting, walking and setting down actions of all the workers involved. While transporting material by trucks, the truck should be operated at safe limit speed as specified and special care should be taken at blind corners and doorways. During storing material, it should be ensured that the electrical panels and installations and fire extinguishers and hoses are kept clear and have free accessibility. Also the pathways, entries and exits should always be kept clear for movement. The use of racks and bins enables more storage capacity, easy movement of material from one place to another and ensures better safety in an industrial organization

3.3.1 Objectives of Industrial Safety

The objectives of industrial safety are as follows:

1. Industrial safety is needed to check all the possible chances of accidents for preventing loss of life and permanent disability of any industrial employee, any damage to machine and material as it leads to the loss to the whole establishment.
2. It is needed to eliminate accidents causing work stoppage and production loss.

3. It is needed to prevent accidents in industry by reducing any hazard to minimum.
4. It is needed to reduce workman's compensation, insurance rate and all the cost of accidents.
5. It is required to educate all members regarding the safety principles to avoid accidents in industry.
6. It is needed to achieve better morale of the industrial employees.
7. It is required to have better human relations within the industry.
8. It is needed to increase production means to a higher standard of living.

3.4 ACCIDENTS AND THEIR TYPES

The accidents are the mishaps leading injury to man, machines or tools and equipment and may cause injury and result either death or temporary disablement or permanent disablement of the industrial employees. A survey was conducted in 1952 in America which specified that approximately ten thousands industrial persons were killed in accidents and more than lakhs were injured in a year. The accidents are unwanted events or mishaps that result in some sort of injury to men, material, machines, tools, equipment and semi or finished product hence, a loss to the whole establishment. The total cost of these accidents was more than crores of dollars. An industrial accident may be defined as an event, detrimental to the health of man, suddenly occurring and originating from external sources, and which is associated with the performance of a paid job, accompanied by an injury, followed by disability or even death. An accident may happen to any employee under certain circumstances. The said injury or loss may be minor or major in nature and accordingly the accident is termed as non-reportable or reportable kind. It should, however, be understood that no hard and line of demarcation can be laid between these two aspects and their identification varies with the place of application. For example a small burn or cut oft body will be reportable accident in a workshop whereas the same, can be treated by first aid and does not involve any appreciable loss of time, not be considered a reportable accident. Few industries determine the accidents by the extent to which it leads to the disablement of the victim and number of hours or days he is to remain absent from duty on account of the problem. There are others which take into consideration various factors like machine, tools, materials, cost of medicines, loss of production and compensation to be given to the worker who meets with the accident. An accident can be very costly to the injured employee as well as to the employer of the manufacturing concern. Some direct or indirect costs are associated with accidents in industries. The direct costs involve payment of compensation and overheads uncompensated wage losses of the injured employees, cost of medical care and hospitalization. Whereas indirect costs of an accident comprise of costs of damage of machines, materials and plant equipments, costs of wages paid for time lost by workers not injured, costs of wages paid to the victim, costs of investigating agency involving recording and reporting of accidents and its causes, costs of deputing new employee for replacement of the injured employee, cost of decreased production by the substituting victim, cost of delays in production due to accident, cost of reduced efficiency of the victim when he joins the manufacturing concern after getting recovered and cost of lowered production due to reduced morale of employees. An accident is an unexpected event which is likely to cause, an injury. Proper diagnosis of causes of mis-happening and corrective measures of the same always helps in preventing future accidents. Accidents in industries put a heavy burden on society also. All direct and indirect cost to the management will ultimately have to be met by the consumers in terms of increased cost of

product. Also, the financial burden of disabled persons and their dependents have to be born by society. Thus every citizen in a nation has to bear a proportion of the cost of accidents. Every care and prevention therefore should be evolved adopted to prevent accidents to the maximum possible extents. Accidents do not just happen but they are caused because of failure to follow the needed safety precautions and safety rules. If someone is honest with himself, he cannot think of a single accident that could not have been prevented by care. There are various types of common accidents needing due attention to prevent them which are as follows:

1. Near Accident

An accident with no damage or injury is called near accident.

2. Trivial

An accident with very less damage is called trivial.

3. Minor Accident

It is an accident with damage and injury more than trivial.

4. Serious Accident

An accident with heavy damage and lot of injury is called serious accident.

5. Fatal

It is an accident with very heavy damage. There may be loss of lives also.

3.4.1 Effect of Accidents

The adverse effects of the accident are given as under—

(A) Effect on the owner of factory

(*i*) Direct cost of an accident

1. Cost of the compensation paid to the workers.
2. Cost of the money paid for treatment.
3. Cost of the monetary value of damaged tools, equipments and materials.

(*ii*) Indirect cost of an accident

1. Cost of the lost time of injured worker.
2. Cost of the time lost by other employees.
3. Cost of the delays in production.
4. Cost of the time lost by supervisors, safety engineers etc.
5. Cost of the lowered production due to substitute worker.

(B) Effect on worker

1. The industrial workers may get temporary or permanent disability.
2. If the industrial worker dies, his family loses the earner and the compensation never equals to his earnings.
3. Accident also affects the morale of the employees working in the manufacturing environment.

(C) Effect on society

Work connected with injuries put a considerable burden on society also as given as under:

1. Cost of accidents is included in the products, so the society has to pay more prices for the industrial products.
2. If some industrial workers do not come under compensation act, the need for help from society is much greater.
3. Loss of production hours may causes fewer products in market. So more prices if demand is more than production.

3.5 CAUSES OF ACCIDEENTS

The accidents may take place due to human causes, environmental causes and mechanical causes. These causes are discussed as under.

Human Causes

1. Accidents may occur while working on unsafe or dangerous equipments or machineries possessing rotating, reciprocating and moving parts.
2. Accidents occur while operating machines without knowledge, without safety precautions, without authority, without safety devices.
3. Accidents generally occur while operating or working at unsafe speed.
4. Accidents may occur while working for long duration of work, shift duty etc.
5. Accidents commonly occur during use of improper tools.
6. Accidents may occur while working with mental worries, ignorance, carelessness, nervousness, dreaming etc.
7. Accidents occur because of not using personal protective devices.

Environmental Causes

1. Accidents may occur during working at improper temperature and humidity causes fatigue to the workers so chances of accidents increases with workers having fatigue.
2. The presence of dust fumes and smoke in the working area may causes accidents.
3. Poor housekeeping, congestion, blocked exits, bad plant layout etc. may cause accidents.
4. Accidents occur due to inadequate illumination.
5. Improper ventilation in the plant may also leads to industrial accidents.

Mechanical Causes

1. Continued use of old, poor maintained or unsafe equipment may result in accidents.
2. Accidents commonly occur due to use of unguarded or improper guarded machines or equipments.
3. Unsafe processes, unsafe design and unsafe construction of building structure may lead to accidents in the plant.
4. Accidents occur due to improper material handling system and improper plant layout.
5. Accidents may occur due to not using of safety devices such as helmets, goggles, gloves, masks etc.

However the other general causes of accidents in workshops are listed under:

1. Because of ignorance to work with equipments, hand tools, cutting tools and machine tools.
2. Operating machine and equipments without knowledge.
3. Extra curiosity to work without knowing.
4. Due to poor working conditions.
5. Because of speedy work.
6. Improper method to work.
7. Due to use of improper tools.
8. Because of lack of discipline.
9. Uninterested in work.
10. Due to carelessness.
11. Due to over confidence.
12. Bad working environment.
13. Because of excessive over times duty by industrial workers.
14. Dangerous materials with which to work.
15. Lack of cleanliness.
16. Due to poor planning.

In a conducted survey, it was observed that most of the accidents, to the tune of 98%, could be easily avoided provided due precautions and care were adopted well in time. It was stressed that accidents do happen but are caused due to the failure of one element or the other. The most unfortunate and most common factor in occurring accidents is the human element which occurs due to non-observance of the safety measures or safety rules. The past statistics also reflects that the causes of accidents as well as the nature of accidents depend entirely on the extent to which safety measures are adopted and not the manufacturing processes or operation. The common causes which lead to accidents may be improper acts by industrial personnel which result in violation of safety rules and non -observance of safety precautions, due to improper tools, machinery and equipments or their unsafe or improper use due to unsafe working position and unsafe working conditions in manufacturing areas.

Some major factors namely technical, unsafe working conditions, mechanical, environment, human cause, unsafe acts and other personal factors are most responsible for accidents. Technical causes or unsafe conditions involves deficiencies in plant, equipment, tools, machinery, materials handling system, general work environment etc. Mechanical causes involve unsafe design and construction of tools and devices, cutting tools, machines tools and mechanical equipments, hazardous arrangement such as piling, over-loading etc, improper guards a against dangerous machine components, defective tool and equipments, improper material handling, leaking valves of acid and poisonous gases, and use of untested boilers and pressure vessels. Environmental factors indicate improper physical and atmospheric surrounding conditions of work which indirectly promote the occurrence of accidents These factors include too low temperature to cause shivering, too high temperature to cause headache and sweating, too high a humidity (in textile industry) to cause discomfort, fatigue and drowsiness, inadequate illumination causing eyestrain, glares, and shadows, presence of dust, fumes and smokes in

industries such as foundries, chemical , paper and sugarcane etc. Lack of adequate ventilation, high speed of work because of huge work load, more number of working hours and over and above them the tendency of the employer to insist for over time work, inadequate rest periods in between works, noise, bad odor and flash coming from the nearby machinery, equipment or processes, and poor housekeeping are also personal factors.

A large number of accidents can be avoided if proper safety measures and safety rules are adopted in manufacturing areas. Some of the important causes of accidents involve violation of safety rules, not using of safety devices, improper use of gadgets and machine controls, non-development of safety working habits, ignorance of the operation of tools, machine and equipments operation, unsafe working conditions, monotony and work-relating stresses, wear and tear of the functional components, explosive and inflammable material etc.

3.6 COMMON SOURCES OF ACCIDENTS

A large number of revolving, rotating, reciprocating and moving parts of machinery can be said as the sources of danger and require guarding for protection against accidents. Extensive studies reveal that some characteristic groups of dangerous parts are acting as common sources of accidents in workshops. Many such major sources are as under.

1. Revolving parts, viz. pulley, flywheels, worms, worm wheel, fan, gears, gear trains, gear wheels etc.
2. Projecting fasteners of revolving parts; like bolts, screws, nuts, key heads, cotters and pins etc.
3. Intermittent feed mechanisms, viz., tool feed of planer; table feed of a shaper, ram feed of power presses and similar other applications.
4. Revolving shafts, spindles, bars, mandrels, chucks, followers and tools like drills, taps, reamers, milling cutters, and boring tool etc.
5. Rotating worms and spirals enclosed in casings, such as in conveyors and revolving cutting tool, like milling cutters, circular saw blade, saw band, circular shears and grinding wheels, etc.
6. Reciprocating tools and dies of power presses, spring hammer, drop hammers, and reciprocating presses, reciprocating knives and saw blade such bow saw, shearing and perforating machines and the cutting and trimming machine and power hack-saws etc.
7. Moving parts of various machines, like those of printing machines, paper-cutters and trimmers, etc.
8. Revolving drums and cylinders without casing, such as concrete and other mixers, tumblers and tumbling barrels, etc.
9. High speed rotating cages such as in hydro-extractors.
10. Revolving weights, such as in hydraulic accumulator or in slotting machines for counter-balance.
11. Nips between meshing racks and pinions of machine parts
12. Nips between reciprocating parts and fixed components, such as between shaper table and the fixture mounted on it or a planer table and table reversing stops, etc.
13. Nips between crank handles for machine controls and fixed parts.

14. Projecting nips between various links and mechanisms, like cranks, connecting rods, piston rods, rotating wheels and discs, etc.
15. Projecting sharp edge or nips of belt and chain drives; via belt, pulleys, chains sprockets and belt fasteners, spiked cylinders etc.
16. Nips between revolving control handles and fixed parts traverse gear handles of lathes, millers, etc.
17. Moving balance weights and dead weight, hydraulic accumulators, counter-balance weight on large slotting machines, etc.
18. Revolving drums and cylinders uncased, tumblers in the foundry, mixers, varnish mixers etc.
19. Nips between fixed and moving parts such as buckets or hoppers of conveyors against tipping bars, stops or parts of the framework.
20. Nips between revolving wheels or cylinders and pans or tables, sand mixers, crushing and incorporating mills, mortar mills, leather carrying machines, etc.
21. Cutting edges of endless band cutting machines, wood working, and log cutting metal find stone-cutting band saws, cloth-cutting band knives, etc.
22. Nips between gears and racks strips, roller drives, presses, planning machine drives, etc.

3.7 PREVENTIVE MEASURES

Few safety measures commonly used in industries comprise of the proper safety guards for reciprocating machine components such as drop hammers, presses, shaper, slotter, power hacksaw, paper cutters etc., fencing of dangerous and rotating parts like revolving shafts, incorporating safety devices such as safety valves, rigid construction of heavy items like hoists, cranes etc, proper insulation of electric wire and earthing of electric appliances, wearing appropriate safety shoe and other necessary items for, body protection, maintenance cleanliness of shop floor, removal of metal chips with proper protection, avoiding fire hazard. Safety while working safely in any shop is the safety of human being and the safety of workshop machinery. Hence there is a great need for the study of the domain of industrial safety for accidents prevention and good house keeping is the utmost. Safe working conditions in any industry may help to minimize the number of accidents taking place, prevent premature death of talented employee, prevent needless pain and suffering to industrial employees, reduce damages to equipment and machinery, increase production and reduce production cost. Good housekeeping implies keeping industry clean, look pleasant well illuminated and ventilated so that accidents are minimized, total production and quality are improved and the employee morale is boosted. Careless handling of heavy materials and components is a major source of back and foot injuries. To avoid premature fatigue of transport workers, full use should be made of mechanized materials handling equipment. Use mechanical means of conveyance to ensure the safety of men engaged in material handling. The transport workers should not be asked to lift more than the permissible load. Personal protective devices such as safe hard hats, rubberized hats for protection against liquids /chemicals, ear protectors, face mask/face shields, welding helmet, goggles of case-hardened and clear glass for protection against impact should be used as per the need.

The good housekeeping has been borrowed from the maintenance of domestic properties in the home or house and is now liberally applied to the maintenance of both cleanliness and order in all kinds of business establishments, e.g., industries etc. Cleanliness is a condition wherein buildings, work and rest areas, machinery, equipments and tools are kept free from dirt, dust etc. Necessity of good housekeeping is essential in order to make and maintain a clean and neat factory work in its surroundings. It makes work more pleasant, most satisfying and motivate for all kind of employees to work. The advantages of good house keeping are fewer accidents, increased life of building, machinery, tools, etc., improved employee morale, increased production, better product quality, continuous cleaning reduces housekeeping costs, no time is lost in searching for tools etc, material handling and transportation pick up speed, inspection, maintenance and production control functions become easier, much floor space otherwise occupied by unused raw material and tools. A good house keeping procedure involves plan and project the housekeeping program carefully and completely.

3.8 COMMON SAFTY METHODS

The common methods of safety are as follows:

1. Safety by construction or design.
2. Safety by position.
3. Safety by using fixed guards.
4. Safety by using interlock guards.
5. Safety by using automatic guards.
6. Safety by using trip guards.
7. Safety by using distance guards.
8. Safety by workplace layout and proper working conditions.
9. Safety by proper material handling.
10. Safety by using personal protective devices.

Few of the above methods of safety are discussed as under.

3.8.1 Safety by Construction

Whenever the new tools, devices, equipments and machine are designed, they should be ensured that all their dangerous parts are either enclosed in suitable housings or provided with suitably designed safety guards in order to eliminate any chances of danger that could occur due to exposure of the dangerous parts. A common example involve belt drive and motor in a in drilling machine, lathe, milling or in other machines are enclosed, the back gears and tumbler gears in a lathe are either enclosed or provided with cast iron guards or covers. All control levers and handles of machines should be carefully located to ensure adequate safety in their operation. Generally, lubricating points are provided on the outer surface that the interior parts are not required to be opened every now and then.

3.8.2 Safety by Position

The main principle involved in the method for safety by position is to design the machine in such a way that the dangerous parts are so located or placed that they are always beyond reach of the operator. It is therefore always advisable that all the dangerous parts of the machine should invariably be guarded or enclosed in the body or housing of the machines as

far the design conditions permit. If it is not possible suitable external fencings must be incorporated suitably.

3.8.3 Safety by Using Fixed Guards

Such fixed guards either form an integral part of the machine or are so tightly secured to them that they are not easily removable. In all cases, fixed guards are developed to have a robust and rigid construction and they should be so placed that any access to the dangerous parts of the machine is totally prevented from all directions particularly in the running condition of the machines. Fixed guards adjusted in position remain fixed and they are neither moved nor detached. In some cases the fixed guards are provided at a distance from the danger point. Such a provision will carry a remote feeding arrangement and, therefore, the operator will not be required to go near the dangerous points.

3.8.4 Safety by Using Interlock Guards

An interlocking guard may be mechanical, electrical, pneumatic or some sort of a combination of these. Such guards cannot be removed and the dangerous parts are not exposed until and unless the machine is totally stopped. Similarly, the machine cannot be started to work unless the guards return in position and protects the dangerous parts. It is essential that such guards should always acquire their positions to guard the dangerous parts before the machine can be started,. Such arrangements prevent the starting and operation of the machine in case the interlocking device fails and remain closed in position until the dangerous part is completely at rest. Scotch interlocking and control interlocking designs of these guards are common used to protect accidents. The former interlocking consists of a solid metal piece, called scotch connected to it which is so located that it remains between two moving parts of the machine. This prevents the machine from starting so long as the same is not removed and the guard brought in proper position for protection. The latter comprises of the movable portion of the guard as connected to some starting device or mechanism of the machine viz., fast and loose pulleys, clutch, starter of the motor or tile hydraulic valve, etc. This connection is made in such a way that it will not allow the operation of the said device or mechanism until and unless the guard is brought in protecting position, which automatically enables its removal from that position from where it prevents the operation of the starting mechanism.

3.8.5 Safety by Using Automatic Guards

The main principle of an automatic guard is that its operation is actuated by some moving part of the machine. Automatic guard and machine operation is so linked that the part will automatically bring the guard in protecting position before the operation of the machine starts. The design of this guard is of such a kind that it automatically forces the operator to move away from the dangerous area of work before the operation starts. Such arrangement of such guard does not permit the operator access to this area again until and unless the machine stops. The use of such guard is largely favored for heavy and slow acting machines like heavy power presses.

3.8.6 Safety by Using Distance Guards

Distance guard helps to fence the dangerous components of machine such as bars or rails and position them at a suitable distance from the machine such that even operator by chance, extends his hands over it, his fingers, clothes or any of the body does not reach within the area of dangerous parts. For additional safety, some sort of tripping device should always be incorporated to stop the machine rapidly in case of an accident.

3.8.7 Safety by Using Trip Guards

Trip guard in machine is comprised with tripping device which enables quick stopping or reversal of the motion of machine as soon as the operator approaches within the reach of dangerous parts. Tripping device and the trip guard works in close conjunction with each other during problematic situations.

3.8.8 Safety by Workplace Layout and Proper Working Conditions

Some safety using workplace layout and proper working conditions are given as under:

1. A suitable layout and proper working conditions play an important role in preventing accidents which would have otherwise occurred.
2. Moving path or passage ways should be clearly marked and never be obstructed.
3. Every employee should have enough space to move and operate the machine.
4. The floor condition must be of non-skid kind. It should act as a satisfactory plane which can be easily cleaned.
5. Height of working rooms should be adequate for proper ventilation and lighting.
6. Fire walls should be used to separate various compartments.
7. Windows should have adequate size and should be in adequate numbers.
8. Illumination should be sufficient, continuous, uniform and free from glare.
9. Proper ventilation should be there in workplace.
10. Noise level should be proper if any. If it is high, use silencers to minimize the noise level.

3.9 TYPES OF SAFETY

The fo1lowing general types of safety are considered in the workshop

1. Safety of self.
2. Safety of job.
3. Safety of machines tools.

However there are general safety precautions to be adopted while working in any workshop

3.9.1 General Safety Precautions while Working in a Workshop

1. One should not leave the machine ON even after the power is OFF and until it has stopped running completely. Someone else may not notice that the machine is still in motion and be injured.
2. Operator should not talk to other industrial persons when he is operating a machine.
3. One should not oil, clean, adjust or repair any machine while it is running. Stop the machine and lock the power switch in the OFF position.
4. One should not operate any machine unless authorized to do so by the authorize person in the shop.
5. Always check that work and cutting tools on any machine are clamped securely before starting.
6. The floor should be kept clean and clear of metal chips or curls and waste pieces.

Put them in the container provided for such things. Scraps and chips or curls may cut through a shoe and injure the foot.

7. Defective guards must be replaced or repaired immediately.
8. One should not operate any machinery when the supervisor or instructor is not in the shop.
9. All set screws should be of flush or recessed type. Projecting set screws are very dangerous because they catch on sleeves or clothing.
10. One should not try to stop the machine with hands or body.
11. Only trained operator should operate machine or switches as far as possible.
12. Always take help for handling long or heavy pieces of material.
13. Always follow safe lifting practices
14. No one should run in the shop at work time.
15. Always keep your body and clothes away from moving machine parts. Get first aid immediately for any injury.
16. Never talk to anyone while operating the machine, nor allow anyone to come near you or the machine.
17. Stop the machine before making measurements or adjustments.
18. Operator should concentrate on the work and must not talk unnecessarily while operating the machines.
19. Never wear necktie, loose sweater, wristwatch, bangles, rings, and loose fitting clothing while working in workshop.
20. Always wear overcoat or apron.
21. Stop machines before attempting to clean it.
22. Make sure that all guards are in their place before starting to operate a machine.
23. Do not attempt to operate a machine until you have received operating instructions.
24. Be thoroughly familiar with the 'stop' button and any emergency stop buttons provided on the machines.
25. Remove burrs, chips and other unwanted materials as soon as possible. They can cause serious cuts.
26. Do not leave loose rags on machines.
27. Wash your hands thoroughly after working to remove oils, abrasive particles, cutting fluid, etc.
28. Report all injuries to the foreman, howsoever small. Cuts and burns should be treated immediately.
29. Keep the work area clean.
30. Keep your mind on the job, be alert, and be ready for any emergency.
31. Always work in proper lighting.
32. On should not lean against the machines.

3.9.2 Safety Precautions while Working with Different Hand Tools

(A) Screw Drivers

1. When working on electrical equipment use only a screw driver with an approved handle.
2. One should wear goggles when re-sharpening screw-driver tips.
3. Screws with burred heads are dangerous and must be replaced or the burrs removed with file or an abrasive cloth.
4. One should use the correct tip of screw drivers while screwing. Too arrow or too wide tip will damage the work.

(B) Wrenches

1. One should not hammer a wrench to loosen a stubborn fastener, unless the tool has been specially designed for such treatment.
2. Always pull on a wrench. One can have more control over the tool if pulling instead of pushing and there is less chance of injury.
3. It is dangerous practice to lengthen the wrench handle for, additional leverage. Use a larger wrench.
4. Choose a wrench that fit properly. A loose fitting wrench may slip and round off the corners of the bolt head and nut.
5. When using wrenches clean grease or oil from the floor in the work area. This will reduce the possibility of slipping and losing balance.

(C) Hammers

1. One should not operate the hammer unless its head is tightly fixed to the handle.
2. Place the hammer on the bench carefully. A falling hammer can cause serious foot injuries.
3. Never strike two hammers together. The faces are very hard and the blow might cause a chip to break off.
4. Never hold the hammer too far on the handle when striking a blow.
5. Unless the blow is struck squarely, the hammer may glance of the work.

3.9.3 Safety Precautions while Working with Different Cutting Tools

(A) Files

1. One should always use a file card to clean the file. Never use your hand. The chips may penetrate in hand and cause a painful infection.
2. One should not use a file without a handle.
3. Short burns formed in filling may cause serious cuts. Always use a piece of cloth to wipe the surface being field.
4. Files are highly brittle and should never be used as a hammer otherwise the file will break.
5. Never hammer on a file. It may shatter and chips fly in all directions.

(B) Chisels

1. One should always hold the chisel in such a manner that the hammer blow may not miss the chisel to injure your hand.

2. Edges of metal cut with the chisel are often sharp and cause bad cuts.
3. Flying chips are dangerous. Wear transparent plastic safety goggles and use a shield, when using a chisel, to protect yourself and those working near you.
4. Sharp edges of chisels are removed by grinding or filing.
5. Mushroomed head of the chisel should be removed by grinding.

(C) Saws

1. One should not test the sharpness of the blade by a running a finger across the teeth.
2. One should not brush away the chips with your hand.
3. All hard blades can shatter and produce flying chips. Wear your toggles.
4. One should not be sure that the blade is properly tensioned.
5. Store the saw so that you will not accidentally reach into the teeth when you pick it up.
6. If the blade breaks while you are on cutting stroke, your hand may strike the works and cause an injury. Therefore saw operator should work carefully.

(D) Reamers

1. One should remove all bars from the reamed holes.
2. Never use your hands to remove chips and cutting fluids from the reamer and work. One should use a piece of cotton waste.

(E) Taps and Dies

1. One should use a brush to clean away chips formed by hand threading. Never use your hand.
2. One should always wear goggles if the tap, die or threaded piece is to be cleaned with compressed air.
3. Tap operator should also be careful that other person working in the area also wearing goggles.
4. Handle broken taps as you would handle broken glass. They are sharp edges and are dangerous to handle.
5. Wash you hands after using cutting fluid. Skin-rashes caused by some cutting fluids can develop into a serious skin disorder if they are left on the skin for a long period.
6. Take care of any cuts immediately. Infection may occur when injuries are not properly treated.

(F) Abrasives

1. If the lathe is used for polishing make sure that the machine is protected from the abrasive grains that fall from the polishing wheels during polishing. They can cause rapid wear of the precision parts.
2. One should not rub fingers or hand across a piece that has just been polished by abrasive.
3. Cuts and burns should always be treated immediately by using first aid facility.
4. One should remove all abrasive particles by washing them thoroughly after the polishing operation.

3.9.4 General Safety Precautions while Working in Machine Shop

The following safety precautions or guidelines are generally adopted for every metal cutting or machining shop. They must be strictly followed for safety. Specific safety guidelines for some of the machine process like lathe, drilling, shaping, planning slotting, grinding, milling, and finishing operations are also described in the following sections.

1. One should use the correct tools and work holding devices recommended for the process.
2. One should hold the work piece and tool securely on the machine.
3. One should clamp the tool correctly. An overhanging tool may cause catastrophic failure of the tool, work piece or the machine tool.
4. One should not try to remove chips from the machine with your hands.
5. Never use compressed air from mouth. Use brush.
6. One should not touch a job-piece with bare hands while doing inspection or removing it from the machine. Use gloves always.
7. One should operate the machine at recommended operating conditions based on work material and tool material combination and other cutting conditions specified.
8. One should use recommended coolant depending upon work-tool material combination.
9. During machining ductile materials, use chip breakers and chip guards.
10. One should re-sharp the tools immediately when it starts producing rough surfaces on the job-piece or produces chatter.
11. One should not run the machines at speed higher than recommended. It may produce vibrations and chatter and damage job-piece, tool, or both.
12. Provide sufficient approach and over travel distances wherever necessary.
13. In case of power failures, switch off the machine and retrieve tool from the workpiece.
14. One should wear goggles to protect eyes from flying chips.
15. Machines are governed by the old clinch garbage input, garbage output. The skill of the operator is often the limiting factor for the machining operation.
16. Stop machine before attempting to clean, removing tool or workpiece.

3.9.5 General Safety Guidelines while Working on Grinding Machines

1. Grinding wheels badly worn or cracked should be replaced
2. The grinding wheel should be properly balanced while mounting.
3. One should ensure that no combustible or flammable materials are nearby that could be ignited by sparks generated by grinding wheels during grinding operations.
4. One should allow the grinding wheel to reach full speed before stepping it into the grinding position. Faulty wheels usually break at the start of an operation.
5. Always use the face of the grinding wheel that is meant for grinding.
6. One should slowly move job-pieces across the face of wheel in a uniform manner. This will keep the wheel sound.
7. Grinding wheels should be checked properly timely for soundness. Suspend the wheel on a string and tap it. If the wheel rings, it is probably sound.
8. One should not use a grinding wheel that has been dropped or dealt with a heavy blow, even if there is no apparent damage.

9. Before using a new grinding wheel, let it run for a few seconds at the full speed to check and make sure that it is perfectly balanced.
10. One should not operate the grinding wheel beyond its bursting speed.
11. Follow the manufacturer's instructions for the correct use of the grinding wheels.
12. Always wear goggles during grinding or allied processes.

3.9.6 Safety Precautions while Working on Lathe Machine

1. One should always be sure that all guards are in place before running the machine.
2. Always clamp the work and tool properly with correct size of work and tool holding device.
3. Always keep the machine clear of tools.
4. Machine should be stopped before making measurements or adjustments.
5. Wear an apron or a properly fitted shop coat. Goggles should also be used.
6. One should remove necktie, wrist watch and jewellery while working.
7. One should not operate the lathe until he knows the proper procedure.
8. One should check the work frequently when it is being machined.
9. One should check the face-plate or chuck by hand to be sure that there is no danger of the work striking any part of the lathe.
10. Stop the machine and remove chips with pliers. One should not remove the chips by hand.

3.9.7 Safety Precautions while Working in Casting shop

Similar to other manufacturing processes, the following safety precautions need to be taken in the casting shop also.

1. One should use mask to avoid excessive inhalation of the dust, which may cause serious problem to health.
2. Always wear protective clothes to keep safe from the heat radiating from the melting process.
3. All foundry men should wear protective clothes, glasses, shoes, and gloves while handling molten metal for casting process.
4. One should be alert as severe burn injury can result from spillage of the molten metal.
5. Always use proper ventilation to protect from molten metal fumes and gases that evolve from the mould during pouring.
6. One should not touch hot moulds and castings.
7. Always use earplugs to safeguard against the heavy noise.
8. One should always keep clean the work area.

3.9.8 Safety Precautions while Working in Welding shop

(A) Gas welding

1. One should not use a leaking gas cylinder.

2. One should not handle oxygen cylinders, valves, regulators, hoses or fittings with oily hands.
3. Welder should not mix the gases in one cylinder.
4. No one should transfer the gas from one cylinder to another.
5. One should clearly mention on the cylinders the type of gas in it (i.e. oxygen, acetylene, etc.).
6. One should use nose masks where the local exhaust ventilation is not practicable. Insist the safety officer to provide proper ventilation system.
7. Always avoid skin contact with fluxes, which contain fluorides. If they will penetrate the skin, they produce severe irritation.
8. No one should weld the parts, which are coated with toxic material such as lead, cadmium, zinc, mercury, or paint containing toxic before materials. Any such coatings must be removed prior to welding.
9. Acetylene gas should not be brought in contact with the unalloyed copper directly (except in torch) which may result in a violent explosion.

(B) Arc welding

1. One should use protective clothing and eye protection devices while performing arc welding operation, otherwise radiation from electric arc will damage the retina of eyes. One has to be sure that other people standing nearby also uses eye-protection devices from ultraviolet rays.
2. Always use ear protection devices such as muffler because excessive noise caused during the process of arc welding may cause temporary or permanent hearing loss.
3. Welder should keep clothing and gloves dry.
4. Always keep welding cables free of grease and oil.
5. One should prevent the non-insulated portion of the electrode holder from touching the welding ground or job-piece when the current is on.
6. Always keep the body insulated from both the work and the metal electrode holder.
7. One should carry out the welding process by standing on the insulating material like dry wood rather than on a grounded metal structure.
8. It is easier and safer to establish an arc on a clean surface than on a dirty or rusty one.
9. Always turn the welding machine off when it is not in use.
10. One should not change the polarity switch when the machine is under use. This will burn the surface of the switch and the resulting arc can cause injury to the welder.
11. Always avoid using electrode holders with defective jaws or poor insulation.

3.10 FACTORY ACT REGULATIONS WITH REGARD TO SAFETY

The objective of avoiding loss of lives and other industrial losses through accidents lead to follow the factory act regulation. For example Workman Compensation Act-1923 provides employer's liability for compensation. Compensation depend upon the condition that injury must have resulted either in death or partial disablement of an employee for a period

acceding three days during employment and accident must have arisen out of and during employment. Factory act 1948 defines various terms of factories like manufacturing process, machinery, worker, power, prime mover etc. It lays down rules for fencing of machinery for safeguard nearby work and machinery in motion. Now a days, Indian factory act of 1949 is in force which presently also provides for a large number of regulations regarding safety for health of workers which include cleanliness, ventilation and temperature controls, humidity, protection against inhalation of dust and fumes, drinking water, overcrowding and proper locations for spittoons etc.

This act also specify some important regulations with regard to the age of employees for specific nature of jobs and also their respective permissible working hours in a day, week and month in order to avoid excessive fatigue and ensure more safety. It also covers some additional regulations regarding welfare of workers, their overtime duties, wages, first-aid provisions and conditions of employment of young persons and women. All such provisions collectively contribute to safe working conditions in the factories.

Beside above, various safety organizations in different parts of the world carry on regular studies and research in causes of accidents and the methods of their prevention. These organizations regularly issue their periodical bulletins in respect of their achievements regarding safety. These bulletins can be referred frequently for keeping in touch with the latest techniques and measures of safety. Few well known such organizations are Safety First Association of India, National Safety Council of U.S.A, International Labor Office, Geneva, Factory Department, Ministry of Labor, H.M.S.O., (U.K.), National Safety Council, Bombay, Industrial Health Organization, Kanpur, All India Institute of Hygiene and Public Health, Calcutta. Indian Council of Medical Research, New Delhi., Bureau of Indian Standards, New Delhi, World Health Organization, The Royal Society for tile prevention of Accidents (ROSPA) London., British Standards, Institution, London., Occupational Safety and Health Administration, Washington D.C, U.S.A., Bureau of Labor Standards, U.S.A, American Society of Safety Engineers, Commonwealth Department of Labor and National Service, Australia. Canadian Industrial Safety Association (CISA), Ontario, Canada, World Safety Organization (WSO), Manila, International Occupational Safety and Health Information Center, Switzerland.

The main objectives of factory act are to provide protection to the workers employed in factories against industrial hazards and to ensure safe and better working conditions. The general provisions in the factory act with regard to the fencing of machinery and other safety measures are summarized below:

Every moving part of a prime mover, fly-wheels connected to prime movers, head and tail races of all water-wheels and turbines, any portion of bar stock that projects beyond the head stock of lathe of in each factory shall be fenced securely by safety guards of robust construction and these guards will always be kept in position while the part or machinery is in operation or motion:

(*i*) All parts of an electric motor, generator and converter, all parts of transmission machinery, all dangerous parts of any other machinery should be securely fenced by means of safety guards unless they are located in such positions and/or their construction ensures adequate safety for every person employed in the factory.

(*ii*) In case it becomes necessary to examine any part or parts of machinery while being in motion only a specially trained adult worker should be deputed for the work.

(*iii*) Precautions against dangerous fumes.

Adequate protection should always be provided against dangerous fume. No person be allowed to enter confined spaces, chamber, tanks etc. in which dangerous fumes are likely to be present. If a manufacturing process is producing dust, fumes, or vapors, sufficient measures should always be taken to prevent inhalation of the same by industrial personnel.

3.10.1 Scope of Factory Act Regulation

Every industrial establishment employing ten or more persons where manufacturing process is carried on with the power and employing twenty or more persons where power is not used for manufacturing process, come under the scope of this act. All types of seasonal and perennial factories are included under this act without any distinction. The factory act has been en-forced in all the states of India. For installing an industry licensing and registration of the factory are also required from the government under the factory act regulation. Every industry should be registered by sending the registration documents to the chief inspector of factory with a written notice containing details of the factory such as the name of the factory, name and address of the factory owner, details of power used type of production.

3.11 ELECTRICAL SAFETY MEASURES

If a person receives electric shock of mild or serious kind, directly or indirectly, the same must be reported as electric accident. In case of stoppage of breathing after electric shock to any victim, one should remove all sorts of obstructions from the mouth of the victim. Then he should sit on his knees near the head of the victim and keep your both hands on his near the collar bone, in such a way that the thumbs of both hands touch each other the fingers remain open. He should press the back of the patient slowly and release the pressure on the back and move up to the shoulders by sliding palms. Then the victim should be pulled upward by holding the patient's arm in between his elbows and shoulders. This process is repeated until patient starts breathing himself.

Based on past experience, a number of rules and regulations have been made for handling of electrical appliances. In industry, an inquiry is normally ordered for electrical accident. Items carrying electricity should be properly insulated. Ageing of insulation withstand capacity and should not be allowed to leak current. Switching contacts and point contacts should be checked periodically to sparking and point heating. Important electric preventive measures are

1. All metallic parts, externally accessible must always be earthed.
2. No inflammable materials are kept near electrical appliances, electric line wires or electric control panels.
3. Electric safety devices like fuse, circuit breakers over-tripping must be always used where ever required.
4. All defective and worn-out electric fittings must be replaced.
5. No untrained persons should be allowed to repair electrical faults.
6. Safety belts, helmet, rubber gloves, boots with rubber soles, and other safety items always are used by electrician while dealing or working with high voltage. These appliances should be provided to all electric mechanics.
7. Overloading of any electric circuit must be avoided.
8. The electric appliances when not in use must be dis-connected from main supply.

9. Power supply should be switched off always during maintenance work. Only authorized person should be allowed to switch on and off' the power supply.
10. One should avoid touching metal case of any electrical apparatus when it is in operation.
11. Proper type of wiring should always be provided in all locations.
12. Periodical inspection should be done to detect the damages.
13. Always avoid overloading on any single point.
14. Good standards of safety items must be maintained as per norms.

3.12 FIRE PREVENTION

Accidents due to fire cause enormous damage to properties, manpower and materials. It can be noted that the origin of fire is combustion. The main factors for combustions are presence of oxygen, availability of combustible materials and rise of temperature to the ignition point for the material. The cause of fire accidents may be electric-short circuit, carelessness and ignorance, spontaneous combustion, riots and rivalry etc. Prevention of the fire involves preventing spreading of fire by covering it with incombustible material, rescuing the affected persons from the spot, cooling ignition point of combustible items, taking suitable precautions and educating the all staff and workers about the possible hazards out of the consumables that spread fires, color coding of pressure vessel containing combustible fluids, maintaining fire extinguisher and water points in shop floor for proper precaution in case fire hazard. In case of outbreak of fire, immediate, corrective action is very much essential in order to provide the best possible chance of extinguishing the fire as quickly as possible, thus reducing danger to life and other damages to the minimum possible extent. As soon as fire breaks out, the fire alarm must be raised to alert all. All employees must be fire conscious and must know the fire drill, position of the nearest fire point and the nearest telephone or fire alarm. Near to equipments such as blow lamps and welding torches, which may lead to fire hazards, a suitable fire-extinguisher should be placed well within the easy reach of every one. Fire drills and fire orders should be displayed on all departmental notice boards and at all fire points. All employees must make themselves familiar with these orders. Fire exits and the escape routes should be clearly marked and kept free from all kinds of obstructions. It is also very important to stop fighting the fire and leave the area as soon as the fire appears to be beyond control or escape route is threatened by fire or smoke obscures or threatens to obscure the escape route. As far as possible, fire-extinguishers should be supported by brackets firmly fixed to the wall at a convenient height at all fire points. There should be an instruction plate for display along each side of an extinguisher, which gives details of operation and the type of fire for which the particular extinguisher is suitable.

The following precautions should be taken for fire prevention:

1. The maximum number of workers and officers should be trained with fire fighting systems and equipments.
2. Keep all flammable liquids in closed containers or in safe cylinders.
3. Effective fire warning signals.
4. All doors should be opened towards outside the workroom as means of escape in case of fire.
5. The doors and windows to be used as exit in case of fire should be easily located. These should be marked with red letters of adequate size.

6. Always select the least flammable liquid that will serve the purpose.
7. One should provide ventilation to prevent any accumulation of vapors.
8. Always provide suitable and adequate means of fire extinguishment.
9. Every operator should be familiar with the location of fire extinguishers and their use (operation).
10. Proper clearance should always be there in between the heating device and any combustible material.
11. Electrical wiring should be proper.
12. Always prohibit smoking, open flames and sparks near the flammable materials.
13. A free passageways and easily open-able windows should be always provided.
14. Provide always suitable means for the safe storage and handling of all fuel used.
15. Use of flammable liquids should be minimized
16. Safe disposal for the flammable liquid wastes must be provided.
17. No one is permitted to accumulate fuels or other combustibles near the source of open fire or spark.

3.13 TYPES OF FIRE

There are three major types of fires which are given as under.

Type 1 Fires occurring due burning of ordinary combustible materials such as wood, cloth and paper. Pouring water is the most effective way for extinguishing this kind of fire.

Type 2 Fires occurring due burning of flammable liquids such as oils, petrol, grease and fat. For extinguishing, blanket or smother this kind of fire, thus excluding oxygen, water must never be used.

Type 3 Fires in this category involve live electrical equipment. The extinguishing agent must be non-conducting of electricity and water must not be used for extinguishing this kind of fire.

There are five basic kinds of fire extinguishers commonly used which are discussed as under.

1. Dry Powder Extinguishers

These extinguishers filled with dry powder may be of the gas pressure or stored air pressure type. They are suitable for use on both Type 2 and Type 3 fires.

2. Foam Extinguishers

These are of two main types commonly called mechanical foam and chemical foam type of fire extinguishers. They are effective against Type 2 fires.

3. Carbon Dioxide Type Fire Extinguishers

These are filled with the carbon dioxide. It is operated by means of a plunger, lever trigger or by opening a valve. It is fitted with a distinctively shaped discharge horn. This type of fire extinguisher has only limited effectiveness against Type 1 kind of fires. It is suitable for extinguishing type 2 and 3 kinds of fires.

4. Water Filled Fire Extinguishers

The soda acid kind is the most common kind of water extinguishers. They are most suitable for extinguishing fire for type 1. Such fires are resulting from ordinary combustible materials such as wood cloth and paper.

5. Vaporizing Liquid Type Fire Extinguishers

They may be filled with either carbon tetrachloride (CTC.) or chlorobromethane (CBM) where as CTC kinds of extinguishers may be of the pump, gas cartridge or stored pressure type. And CBM may be either gas cartridge or stored pressure. These extinguishers are most effective against electrical kind of fire (Type 3).

6. Stored Air Pressure Type Extinguishers

In stored air pressure type extinguishers, the container is pressurized with air when the extinguisher is filled. The extinguisher is trigger operated and operation can be stopped at any time by releasing the trigger grip. It is suitable for type 1 kind of fire only.

7. Gas Pressure Type Extinguishers

In gas pressure type extinguishers the water is expelled under pressure provided by carbon dioxide gas released from cartridge filled inside the container. It is suitable for Type 1 kind of fire.

3.14 FIRST AID

Even after taking all necessary safety precautions and measures, sometimes accidents may also occur in industries. After major or minor accidents, an injured worker requires immediate preliminary treatment in the absence of same his condition may become highly critical. To take care of such situations, industries must employ full time, at least a medical person who has successfully completed his Red-Cross First-Aid Course, and who can give preliminary treatment to the injured person. The injured person may later on be shifted safely to the nearby hospital through the ambulance or otherwise through any vehicle or by other means as per the availability of mode of transportation. Besides the above service, a first-aid personnel should take care of those workers or employees who come across injury by minor cuts, burns or electric shock. The first aid provider should bring the victim in first aid room for further treatment. In case of fatal injury first aid provider should call the doctor as soon as possible or to arrange the ambulance for taking the victim to the hospital. He should deal the victim with full sympathy and make early arrangement to call the family member or some responsible member so that adequate arrangements can be made in hospital for the due care of the victim. If breathing has stopped, he or she should be provided artificial respiration immediately.

For first aid services, a first-aid box containing the following items is always kept ready during working hours in the shops or nearby working places where there are chances accidents to occur.

Items of a First-Aid Box

Items	Name	Quantity
(*i*)	Pair of scissors	1
(*ii*)	Large size sterilized dressings	12

(*iii*)	Medium size sterilized dressings	12
(*iv*)	Small sized sterilized dressings	24
(*v*)	Large size burn dressings	12
(*vi*)	Packets of sterilized cotton wool	2
(*vii*)	Rolled bandages 10 cm wide	12
(*viii*)	Rolled bandages 5 cm wide	12
(*ix*)	Bottle (4 oz) of salvolative having the doze and made of administration indicated on label	1
(*xi*)	Safety pins	2 packets
(*xi*)	Eye drops	1 small bottle
(*xii*)	Adhesive plaster	2 roller
(*xiii*)	4 oz bottle containing KMnO4 crystals, etc.	2
(*xiv*)	4 oz bottle containting a 2% alcoholic solution	1
(*xv*)	Betadine ointment (50mg)	1
(*xvi*)	Saframycine ointment (50mg)	1
(*xvii*)	Detol	1

3.15 QUESTIONS

1. What do you mean by industrial safety? What are major safety objectives?

2. What is an accident? Describe briefly the common causes and sources of accidents.

3. Explain in brief the various methods of safety adopted in plant.

4. Explain briefly the safety precautions associated with material handling in the plant.

5. Describe briefly the general provisions of factories act 1948, regarding safety.

6. Discuss various methods used for artificial respiration required for a victim.

7. How fire can be prevented in industries? Explain in brief.

8. Describe the duty of first aid personnel.

4
CHAPTER

FERROUS MATERIALS

4.1 INTRODUCTION

Engineering materials used to manufacture of articles or products, dictates which manufacturing process or processes are to be used to provide it the desired shape. Sometimes, it is possible to use more than one manufacturing processes, then the best possible process must be utilized in manufacture of product. It is therefore important to know what materials are available in the universe with it usual cost. What are the common characteristics of engineering materials such as physical, chemical, mechanical, thermal, optical, electrical, and mechanical? How they can be processed economically to get the desired product. The basic knowledge of engineering materials and their properties is of great significance for a design and manufacturing engineer. The elements of tools, machines and equipments should be made of such a material which has properties suitable for the conditions of operation. In addition to this, a product designer, tool designer and design engineer should always be familiar with various kinds of engineering materials, their properties and applications to meet the functional requirements of the design product. They must understand all the effects which the manufacturing processes and heat treatment have on the properties of the engineering materials. The general classification

4.2 CLASSIFICATION OF ENGINEERING MATERIALS

A large numbers of engineering materials exists in the universe such as metals and non metals (leather, rubber, asbestos, plastic, ceramics, organic polymers, composites and semi conductor). Some commonly used engineering materials are broadly classified as shown in Fig. 4.1. Leather is generally used for shoes, belt drives, packing, washers etc. It is highly flexible and can easily withstand against considerable wear under suitable conditions. Rubber is commonly employed as packing material, belt drive as an electric insulator. Asbestos is basically utilized for lagging round steam pipes and steam pipe and steam boilers because it is poor conductor of heat, so avoids loss of heat to the surroundings. Engineering materials may also be categorized into metals and alloys, ceramic materials, organic polymers, composites and semiconductors. The metal and alloys have tremendous applications for manufacturing the products required by the customers.

Metals and Alloys

Metals are polycrystalline bodies consisting of a great number of fine crystals. Pure metals possess low strength and do not have the required properties. So, alloys are produced by

melting or sintering two or more metals or metals and a non-metal, together. Alloys may consist of two more components. Metals and alloys are further classified into two major kind namely ferrous metals and non-ferrous metals.

(*a*) Ferrous metals are those which have the iron as their main constituent, such as pig iron, cast iron, wrought iron and steels.

(*b*) Non-ferrous metals are those which have a metal other than iron as their main constituent, such as copper, aluminium, brass, bronze, tin, silver zinc, invar etc.

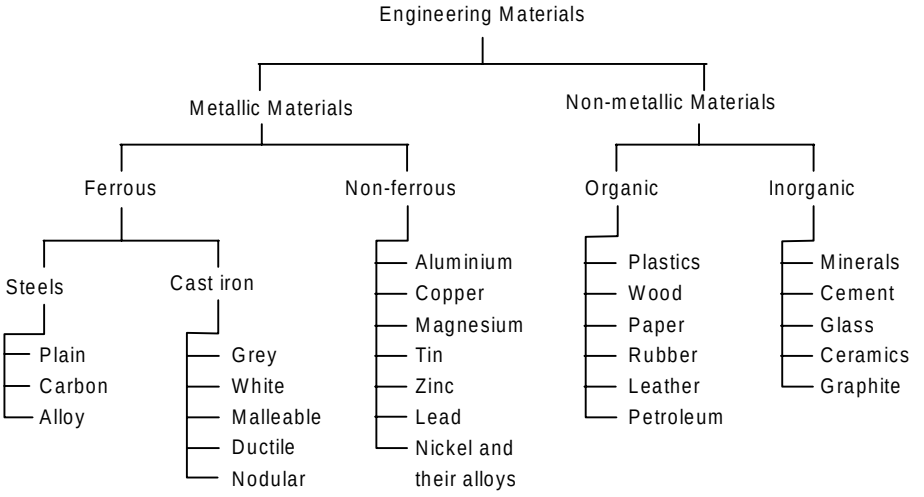


Fig. 4.1 Classification of engineering materials

4.3 FERROUS METALS

Ferrous metals are iron base metals which include all variety of pig iron, cast iron wrought iron and steels. The ferrous metals are those which have iron as their main constituents. The ferrous metals commonly used in engineering practice are cast iron, wrought iron, steel and alloy steels. The basic principal raw material for all ferrous metals is pig iron which is obtained by smelting iron ore, coke and limestone, in the blast furnace. The principal iron ores with their metallic contents are shown in Table 4.1.

Table 4.1 Types of Iron Ore

S.No.	Iron ore	Color	Iron %
1.	Haematite (Fe_3O_4)	Red	70%
2.	Magnetite (Fe_2O_3)	Black	72%
3.	Limonite	Brown	62.5%
4.	Siderite	Brown	48%

4.3.1 Main Types of Iron

1. Pig iron
2. Cast iron

(A) White cast iron
(B) Gray cast iron
(C) Malleable cast iron
(D) Ductile cast iron
(E) Meehanite cast iron
(F) Alloy cast iron

3. Wrought iron
4. Steel
   (A) Plain carbon steels
      1. Dead Carbon steels
      2. Low Carbon steels
      3. Medium Carbon steels
      4. High Carbon steels
   (B) Alloy steels
      1. High speed steel
      2. Stainless steel

Some important ferrous metals, their extraction, composition, properties and their common applications are discussed in detail as under.

4.3.2 Pig Iron

Pig iron was originated in the early days by reduction or iron ores in blast furnace and when the total output of the blast furnace was sand cast into pigs which is a mass of iron roughly resembling a reclining pig. It is roughly of 20" × 9" × 4" in size. It is produced in a blast furnace and is the first product in the process of converting iron ore into useful ferrous metal. The iron ore on initial refining and heating in blast furnace becomes pig iron when the impurities are burnt out in a blast furnace. Pig iron acts as the raw material for production of all kinds of cast iron and steel products. It is obtained by smelting (chemical reduction of iron ore in the blast furnace. It is of great importance in the foundry and in steel making processes. It is partly refined in a cupola furnace that produces various grades of cast iron. By puddling processes, wrought iron is produced from pig iron. Steel is produced from pig iron by various steel making processes such as bessemer, open-hearth, oxygen, electric and spray steel making. The charge in the blast furnace for manufacturing pig iron is

(*a*) Ore — Consisting of iron oxide or carbonate associated with earth impurities.
(*b*) Coke — A fuel
(*c*) Limestone — A flux

In addition to iron, pig iron contains various other constituents in varying form of impurity such carbon, silicon, sulphur, manganese and phosphorus etc. It has the following approximate composition which is as given as under.

Carbon	—	4 to 4.5%	Phosphorus	—	0.1 to 2.0%
Silicon	—	0.4 to 2.0%	Sulphur	—	0.4 to 1.0%
Manganese	—	0.2 to 1.5 %	Iron	—	Remainder

Carbon exists in iron in free form (graphite) and/or in combined form (cementite and pearlite). Pig iron is classified on the basis of contents of free and combined carbon as follows. These classifications are also termed as grades.

1. Grey pig iron (Grades 1, 2 and 3)

Grey pig iron contains about 3% carbon in free form (i.e., graphite form) and about 1% carbon in combined form. This is a soft type of pig iron.

2. White pig iron (Grades 4)

White pig iron is hard and strong. It contains almost all of the carbon in the combined form.

3. Mottled pig iron (Grade 5)

This type of pig iron is in between the grey and white variety. It has an average hardness and molted appearance. The free and combined forms of carbon are in almost equal proportion in mottled pig iron.

4.3.3 Cast Iron

Cast iron is basically an alloy of iron and carbon and is obtained by re-melting pig iron with coke, limestone and steel scrap in a furnace known as cupola. The carbon content in cast iron varies from 1.7% to 6.67%. It also contains small amounts of silicon, manganese, phosphorus and sulphur in form of impurities elements.

4.3.3.1 General properties of cast iron

Cast iron is very brittle and weak in tension and therefore it cannot be used for making bolts and machine parts which are liable to tension. Since the cast iron is a brittle material and therefore, it cannot be used in those parts of machines which are subjected to shocks. It has low cost, good casting characteristics, high compressive strength, high wear resistance and excellent machinability. These properties make it a valuable material for engineering purposes. Its tensile strength varies from 100 to 200 MPa, compressive strength from 400 to 1000 MPa and shear strength is 120 MPa. The compressive strength of cast iron is much greater than the tensile strength. The carbon in cast iron is present either of the following two forms:

1. Free carbon or graphite.
2. Combined carbon or cementite.

The cast iron is classified into seven major kinds as follows:

(*a*) Grey cast iron, (*b*) White cast iron, (*c*) Mottled cast iron (*d*) Malleable cast iron, (*e*) Nodular cast iron, (*f*) Meehanite cast iron. (*g*) Alloy cast iron and The chemical composition, extraction, properties and general applications of these types of cast iron are discussed as under.

4.3.3.2 Grey cast iron

Grey cast iron is grey in color which is due to the carbon being principally in the form of graphite (C in free form in iron). It contains:

C = 2.5 to 3.8%.

Si = 1.1 to 2.8 %

Mn = 0.4 to 1.0%
P = less than 0.15%
S = less than 0.1%
Fe = Remaining

It is produced in cupola furnace by refining or pig iron.

Properties

(*i*) When fractured it gives grey color.
(*ii*) It can be easily cast.
(*iii*) It is marked by presence of flakes of graphite in a matrix of ferrite and pearlite or austenite; graphite flakes occupy 10% of metal volume.
(*iv*) It can be easily machined and possesses machinability better than steel.
(*v*) It possesses lowest melting of ferrous alloys.
(*vi*) It possesses high vibration damping capacity.
(*vii*) It has high resistance to wear.
(*viii*) It possesses high fluidity and hence can be cast into complex shapes and thin sections.
(*ix*) It possesses high compressive strength.
(*x*) It has a low tensile strength.
(*xi*) It has very low ductility and low impact strength as compared with steel.

Applications

The grey iron castings are mainly used for machine tool bodies, automotive cylinder blocks, pipes and pipe fittings and agricultural implements. The other applications involved are

(*i*) Machine tool structures such as bed, frames, column etc.
(*ii*) Household appliances etc.
(*iii*) Gas or water pipes for under ground purposes.
(*iv*) Man holes covers.
(*v*) Piston rings.
(*vi*) Rolling mill and general machinery parts.
(*vii*) Cylinder blocks and heads for I.C. engines.
(*viii*) Frames of electric motor.
(*ix*) Ingot mould. And
(*x*) General machinery parts.
(*xi*) Sanitary wares.
(*xii*) Tunnel segment.

4.3.3.3 White cast iron

The white color is due to the fact that the carbon is this iron is in combined form as iron carbide which is commonly specified as cementite. It is the hardest constituent of iron. It is

produced in cupola furnace by refining or pig iron. The white cast iron may be produced by casting against metal chills or by regulating analysis. The chills are used when a hard and wear resistance surface is desired for products such as for wheels, rolls crushing jaw, crusher plates. The chemical composition of white cast iron is given as under.

C = 3.2 to 3.6%
Si = 0.4 to 1.1 %
Mg = 0.1 to 0.4%
P = less than 0.3%
S = less than 0.2%
Fe = Remaining

Properties

(*i*) Its name is due to the fact that its freshly broken surface shows a bright white fracture.

(*ii*) It is very hard due to carbon chemically bonded with iron as iron carbide (Fe_3C), which is brittle also.

(*iii*) It possesses excellent abrasive wear resistance.

(*iv*) Since it is extremely hard, therefore it is very difficult to machine.

(*v*) Its solidification range is 2650-2065°F.

(*vi*) Shrinkage is 1/8 inch per foot.

(*vii*) The white cast iron has a high tensile strength and a low compressive strength.

Applications

(*i*) For producing malleable iron castings.

(*ii*) For manufacturing those component or parts which require a hard, and abrasion resistant surface such as rim of car.

(*iii*) Railway brake blocks.

4.3.3.4 Ductile cast iron

When small quantities of magnesium or cerium is added to cast iron, then graphite content is converted into nodular or spheroidal form and it is well dispersed throughout the material. The resulting structure possesses properties more like cast steel than like the other grades of cast iron. A typical structure of spheroidal cast iron is shown in Fig. 4.2. Graphite is in spheroidal form instead of in flaky form. Its structure may be modified by alloys or heat treatment, as in steel to produce austenite, acicular, martensite, pearlite, and ferrite structure. Compositions of ductile cast iron are as follows:

Carbon = 3.2 to 4.2%
Silicon = 1.0 to 4.0 %
Magnesium = 0.1 to 0.8%
Nickel = 0.0 to 3.5%
Manganese = 0.5 to 0.1%
Iron = Remaining

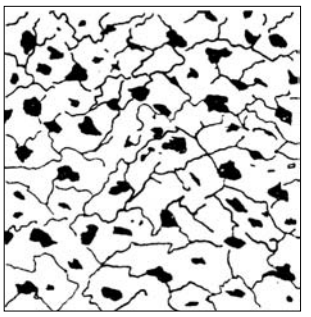


Fig. 4.2 Typical structure of spheroidal cast iron

Silicon is also used as an alloying element since it has no effect on size and distribution of carbon content. The magnesium controls the formation of graphite. But it has little influence on the matrix structure. Nickel and manganese impart strength and ductility. Ductile cast iron has high fluidity, excellent castability, strength, high toughness, excellent wear resistance, pressure tightness, weldability and higher machinability in comparison to grey cast iron.

4.3.3.5 Malleable cast iron

The ordinary cast iron is very hard and brittle. Malleable cast iron is unsuitable for articles which are thin, light and subjected to shock. It can be flattened under pressure by forging and rolling. It is an alloy in which all combined carbon changed to free form by suitable heat treatment. Graphite originally present in iron in the form of flakes which is the source of weakness and brittleness. Carbon in this cast iron is dispersed as tiny specks instead of being flaky or in combined form. The tiny specks have not such weakening effect and casting would not break when dropped. The tensile strength of this cast iron is usually higher than that of grey cast iron. It has excellent machining quality and is used for making machine parts for which the steel forging and in which the metal should have a fair degree of machining accuracy e.g., hubs of wagon, heels small fittings for railway rolling brake supports, parts of agricultural machinery, pipe fittings, hinges, locks etc.

It can be obtained by annealing the castings. The cast iron castings are packed in an oxidizing material such as iron ore or in an inert material such as ground fire clay depends upon the process used either white heart or black heart. The packed casting is put into an oven and is heated around 900°C temperature and is kept at that temperature for about two days and it is then allowed to cool slowly in the furnace itself. Iron ore acting as an oxidizing agent reacts with C and CO_2 escape. Thus annealed cast product is free from carbon. If the castings are packed in an inert material then slow cooling will separate out the combined carbon to temper carbon. To produce malleable casting, first casting is produced which has all combined carbon. The produced castings are then heat-treated in a special manner according to white heart method or black heart method.

White heart malleable iron casting

The castings taken out of the mould are put into a drum having sand and powdered slag. The drum is then closed and kept in the air furnace and it is raised to highly temperature slowly. The temperature is raised to 920°C in two days time, kept at this temperature for nearly up to 50 to 80 hours then the drum is allowed to cool in the furnace (generally air furnaces) at the rate 5 to 10°C per hour till it reaches to room temperature. The whole cycle takes about one weak. During this treatment combined carbon separates out and all the

carbon does not change into graphite state but change in other form of free carbon called tempered carbon.

$$Fe_3C \longrightarrow 3Fe + C$$

This makes the casting less brittle and malleable. The fracture portion of such a casting is dark grey or black in appearance. These castings are specially used in automobile industries.

Black heart malleable iron casting

The castings packed in a drum of oxidizing media which is generally powdered iron ore or powered scale (film of Fe_3O_4 on surface). This close drum is kept in the furnace and heated to 900°C. It is then maintained at this temperature to nearly 40 to 70 hours and allowed to cool slowly in a furnace itself. The castings become malleable like white heart cast iron. The percentage of carbon and silicon should be so selected that it can promote the development of free carbon when these castings are annealed.

Properties

1. Malleable cast iron is like steel than cast iron.
2. It is costly than grey cast iron and cheaper than softer steel.

Applications

Malleable cast iron are generally used to form automobile parts, agriculture implementation, hinges, door keys, spanners mountings of all sorts, seat wheels, cranks, levers thin, waned components of sewing machines and textiles machine parts.

4.3.3.6 Meehanite cast iron

Meehanite cast iron is an inoculated iron of a specially made white cast iron. The composition of this cast iron is graphitized in the ladle with calcium silicide. There are various types of meehanite cast iron namely heat resisting, wear resisting and corrosion resisting kind. These materials have high strength, toughness, ductility and good machinability. It is highly useful for making castings requiring high temperature applications.

4.3.3.7 Alloy cast iron

The cast irons as discussed above contain small percentages of other constituents like silicon, manganese, sulphur and phosphorus. These cast irons may be called as plain cast irons. The alloy cast iron is produced by adding alloying elements like nickel, chromium, molybdenum, copper and manganese in sufficient quantities in the molten metal collected in ladles from cupola furnace. These alloying elements give more strength and result in improvement of properties. The alloy cast iron has special properties like increased strength, high wear resistance, corrosion resistance or heat resistance. The alloy cast irons are extensively used for automobile parts like cylinders, pistons, piston rings, crank cases, brake drums, parts of .crushing and grinding machinery etc.

4.3.3.8 Effect of impurities on cast iron

The cast iron contains small percentages of carbon, silicon, sulphur, manganese and phosphorus. The affect of these impurities on the cast iron are as follows:

(1) **Carbon.** Carbon is one of the important elements in cast iron. It reduces melting point of iron. Pure iron has a melting point of about 1500°C but iron with 3.50% C has melting point of about 1350°C. When carbon is in free form i.e. as graphite form,

the resulting cast iron is known grey cast iron. On the other hand, when the iron and carbon are chemically combined form of cementite, the cast iron will be hard and known as white cast iron.

(2) **Silicon.** Presence of silicon in cast iron promotes the decomposition of cementite into graphite. It also helps to reduce the shrinkage in cast iron when carbon is changed to graphite forms.

(3) **Sulphur.** It makes the cast iron hard and brittle. Since too much sulphur gives unsound casting, therefore, it should be kept below 0.1% for most casting purposes. It is often responsible for creating troubles to foundry men. It will make cast iron hard thereby counteracting the softening influences of silicon. It decreases strength and increases brittleness. It also promotes oxidation of cast iron. Hence, it is kept as low as possible in cast iron.

(4) **Manganese.** It makes cast iron white and hard. It is often kept below 0.75%. It helps to exert a controlling influence over the harmful effect of sulphur. It reduces the harmful effects of the sulphur by forming the manganese sulphide which is not soluble in cast iron.

(5) **Phosphorus.** It increases fusibility and fluidity in cast iron but induces brittleness. It is rarely allowed to exceed 1 %. Phosphorus in irons is useful for casting of intricate shapes and for producing very cheap and light engineering castings. Phosphorus has no effect on the carbon as well as on shrinkage in the cast iron.

4.3.3.9 Comparison among grey, white and spherodidal cast iron

The comparison among grey, white and spherodidal cast iron is given in Table 4.2.

TABLE 4.2 Comparison among Grey, White and Spherodidal Cast Iron

S.No	Grey Cast Iron	White Cast Iron	Spherodidal Cast Iron
1.	It is an alloy of carbon and silicon with iron having grey color when fractured. It is marked by the presence of flakes of matrix of ferrite, pearlite or austenite. Carbon in iron exists in free form as graphite	White cast iron has almost all its carbon as iron carbide. Its broken surface shows a bright white fracture.	Graphite appears as around Particles or spheroids.
2	It has good machinability, high resistance to wear, high vibration damping capacity and high compressive strength.	It has poor machinability, excellent abrasive wear resistance.	It has good machinability, good damping, excellent castability and sufficient wear resistance
3	It is used in machine tool structure, Main-hole covers, cylinder blocks, heads for I.C. engines, gas or water pipes for underground purposes, frames for electric motors, piston rings and sanitary wares.	It is used for producing malleable iron castings and manufacturing those structural component parts which require a hard and abrasion resistant material.	It is used in I.C. engines, paper Industry machinery, machinery for farming and tractor, application, earth moving machinery, valve and fittings, pipes, pumps, compressors and construction machinery.

4.3.4 Wrought Iron

Wrought iron is the assumed approximately as purest iron which possesses at least 99.5% iron. It contains a large number of minute threads of slag lying parallel to each other, thereby giving the metal a fibrous appearance when broken. It is said as a mechanical mixture of very pure iron and a silicate slag. It can also be said as a ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which a minutely and uniformly distributed quantity of slag is incorporated without subsequent fusion. This iron is produced from pig iron by re-melting it in the puddling furnace or air furnace or reverberatory furnace. The molten metal free from impurities is removed from the furnace as a pasty mass of iron and slag. The balls of this pasty mass, each about 45 to 65 kg in weight, are formed. These balls are then mechanically worked to squeeze out the slag and to form it into some commercial shape. This iron contains practically no carbon and therefore can not be hardened.

Chemical Composition

A chemical composition range of typical wrought iron includes:

C = 0.02 – 0.03%	P = 0.05 – 0.25%	Si = 0.02 – 0.10%
S = 0.008 – 0.02%	Mn = 0.0 – 0.02%	Slag = 0.05 – 1.5%

Fe = remainder

Properties

The wrought iron can be easily shaped by hammering, pressing, forging, etc. It is never cast and it can be easily bent when cold. It is tough and it has high ductility and plasticity with which it can be forged and welded easily. Its ultimate strength can be increased considerably by cold working followed by a period of aging. It possesses a high resistance towards corrosion. It can accommodate sudden and excessive shocks loads without permanent injury. It has a high resistance towards fatigue. Its ultimate tensile strength is 2,500 kg/cm^2 to 5,000 kg/cm^2 and the ultimate compressive strength is 3,000 kg/cm^2. It can be elongated considerably by cold working. It has high electrical conductivity. The melting point of wrought iron is about 1530°C. It has elongation 20% in 200 mm in longitudinal direction and 2–5 % in transverse direction. Its poison's ratio is 0.30. It can be easily formed when cold, without the outer side cracking at the formed portion.

Applications

It is used for making chains, crane hooks, railway couplings, and water and steam pipes. It has application in the form of plates, sheets, bars, structural works, forging blooms and billets, rivets, and a wide range of tubular products including pipe, tubing and casing, electrical conduit, cold drawn tubing, nipples and welding fittings, bridge railings, blast plates, drainage lines and troughs, sewer outfall lines, weir plates, sludge tanks and lines, condenser tubes, unfired heat exchangers, acid and alkali process lines, skimmer bars, diesel exhaust and air brake piping, gas collection hoods, coal equipment, cooling tower and spray pond piping.

4.3.5 Steels

Steel is an alloy of iron and carbon with carbon content maximum up to 1.7%. The carbon occurs in the form of iron carbide, because of its ability to increase the hardness and strength of the steel. The effect of carbon on properties of steel is given in Fig. 4.3. Other elements e.g. silicon, sulphur, phosphorus and manganese are also present to greater or lesser amount to import certain desired properties to it. Most of the steel produced now-a-days is plain

carbon steel. Carbon steel has its properties mainly due to carbon content and does not contain more than 0.5% of silicon and 1.5% of manganese.

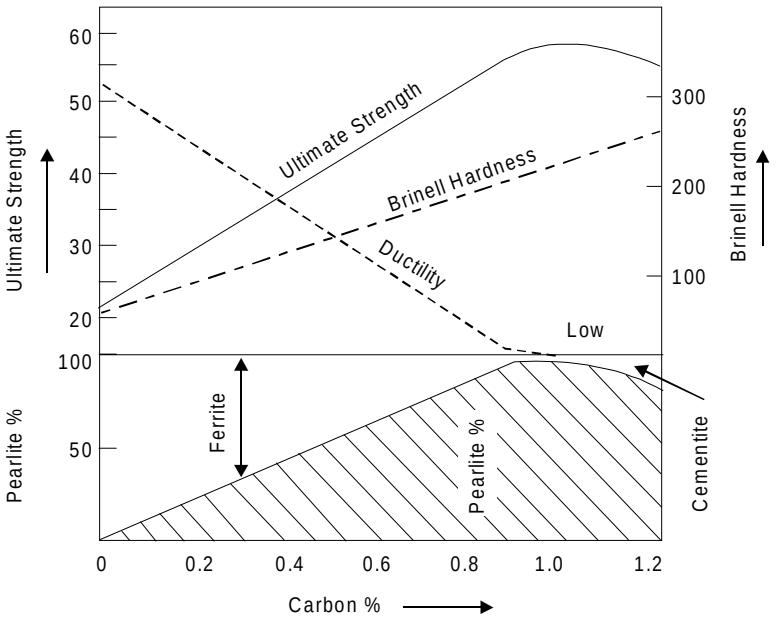


Fig. 4.3 Effect of carbon on properties of steel

For checking microstructure of steel, its specimen is prepared by preparing a flat mirror surface on small piece of metal through rubbing by sand papers, polishing and buffing etc. This surface is then followed by etching with a chemical solution. The chemical solution reacts with various constituents in varying degree to reveal crystal structure clearly. The revealed structure is then viewed through powerful microscope. The viewed micro structures for different steel are depicted in Fig. 4.4.

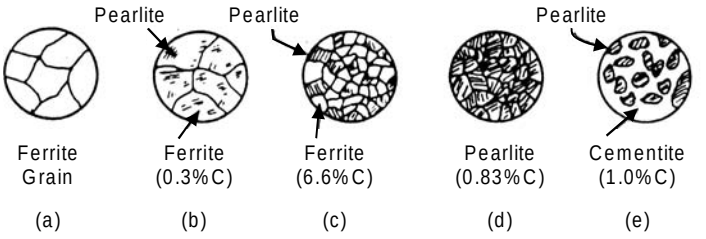


Fig. 4.4 Micro structure of steel

4.3.5.1 Effect of impurities on steel

The effects of impurities like silicon, sulphur, manganese and phosphorus, on steel as discussed under.

1. **Silicon.** Silicon content in the finished steel usually ranges from 0.05 to 0.30%. It is added in low carbon steels for preventing them from becoming porous. It helps in removing the gases and oxides. It prevents blow holes there by making steel tougher and harder.

2. **Sulphur.** It renders free cutting properties in steel. It is found in steel either as iron sulphide or manganese sulphide. Iron sulphide due to its low melting point, produces brittleness whereas manganese sulphide does not affect so much. Therefore, manganese sulphide is less objectionable in steel than iron sulphide.
3. **Manganese.** It serves as a valuable deoxidizing and purifying agent, in steel. Manganese also combines with sulphur and thereby decreases the harmful effect of this element remaining in the steel. It increases wear resistance, hardness and strength and decreases machineability. When used in ordinary low carbon steels, manganese makes the metal ductile and of good bending quantities. In high speed steels, it is used to tougher the metal and to increase its critical temperature.
4. **Phosphorus.** It induces brittleness in steel. It also produces cold shortness in steel. In low carbon steels, it raises the yield point and improves the resistance to atmospheric corrosion. The sum of carbon and phosphorus usually does not exceed 0.25%.

To produce needed improvement in properties of plain carbon steel, certain elements in steel are alloyed for specific purposes to increase wearing resistance, electrical and mechanical properties which cannot be obtained in plain carbon steels.

The steel may be of various kinds and few important types are explained as under.

4.3.5.2 Plain carbon steel

Plain carbon steel is an alloy of iron and carbon. It has good machineability and malleability. It is different from cast iron as regards the percentage of carbon. It contains carbon from 0.06 to 1.5% whereas cast iron possesses carbon from 1.8 to 4.2%. Depending upon the carbon content, a plain carbon steels can divided to the following types:

1. Dead carbon steel — up to 0.15% carbon
2. Low carbon or mild steel — 0.15% to 0.45% carbon
3. Medium carbon steel — 0.45% to 0.8% carbon
4. High carbon steel — 0.8% to 1.5% carbon

Each type is discussed as under.

DEAD CARBON STEEL

It possesses very low percentage of carbon varying from 0.05 to 0.15%. It has a tensile strength of 390 N/mm^2 and a hardness of about 115 BHN. Steel wire, sheets, rivets, screws, pipe, nail and chain are made from this steel. This steel is used for making camshafts, sheets and strips for fan blades, welded tubing, forgings, chains, stamping, rivets, nails, pipes, automobile body etc.

LOW CARBON OR MILD STEEL

Low carbon steel is sometimes known as mild steel also. It contains 0.20 to 0.30% C which has tensile strength of 555 N/mm^2 and hardness of 140 BHN. It possesses bright fibrous structure. It is tough, malleable, ductile and more elastic than wrought iron. It can be easily forged and welded. It can absorb shocks. It rusts easily. Its melting point is about 1410°C. It is used for making angle, channels, case hardening steel, rods, tubes, valves, gears, crankshafts, connecting rods, railway axles, fish plates, small forgings, free cutting steel shaft and forged components etc.

Applications

1. Mild steel containing 0.15 to 0.20% carbon

   It is used in structure steels, universal beams, screws, drop forgings, case hardening steel, bars, rods, tubes, angles and channels etc.

2. Mild steel containing 0.20-0.30% carbon

It is used in making machine structure, gears, free cutting steels, shafts and forged components etc.

MEDIUM CARBON STEELS

Medium carbon steel contains carbon from 0.30 to 0.8%. It possesses having bright fibrous structure when fractured. It is tough and more elastic in comparison to wrought iron. It can be easily forged, welded, elongated due to ductility and beaten into sheets due to its good malleability. It can easily absorb sudden shocks. It is usually produced as killed or semi killed steels and is harden able by treatment. Hardenability is limited to thin sections or to the thin outer layer on thick parts. Its tensile strength is better than cast iron and wrought iron but compressive strength is better than wrought iron but lesser than cast iron. It rusts readily. Its melting point is 1400°C. It can be easily hardened and it possesses good balance of strength and ductility.

It is generally used for making railway coach axles, bolts, connecting rods, key stock, wires and rods, shift and break levers, spring clips, gear shafts, small and medium forgings, railway coach axles, crank pins on heavy machines, spline shafts, crankshafts, forging dies, set screws, die blocks, self tapping screws, clutch discs, valve springs, plate punches, thrust washers etc. The applications of different kinds of medium carbon steel are given as under.

Applications

1. **Plain carbon steels having carbon % 0.30 to 0.45.** Axles, special duty shafts, connecting rods, forgings, machinery steel, spring clips, turbine, rotors, gear shafts, key stock, forks and bolts.
2. **Plain carbon steels having carbon % 0.45 to 0.60.** Railway coach axles, crank pins, crankshafts, axles, spline shafts, loco tyres.
3. **Plain carbon steels having carbon % 0.60 to 0.80**. Drop forging dies, die blocks, bolt heading dies, self-tapping screws, valve spring, lock washers, hammers, cold chisels, hacksaws, jaws for vices etc.

HIGH CARBON STEELS

High carbon steels **(HCS)** contain carbon from 0.8 to 1.5%. Because of their high hardness, these are suitable for wear resistant parts. Spring steel is also high carbon steel. It is available in annealed and pre-tempered strips and wires. High carbon steel loses their hardness at temperature from 200°C to 250°C. They may only be used in the manufacture of cutting tools operating at low cutting speeds. These steels are easy to forge and simple to harden. These steels are of various types which are identified by the carbon percentage, hardness and applications

HCS containing 0.7 to 0.8% carbon possesses hardness of 450-500 BHN. It has application for making cold chisels, drill bits, wrenches, wheels for railway service, jaws for vises, structural wires, shear blades, automatic clutch discs, hacksaws etc.

Steel containing 0.8 to 0.9% C possesses hardness of 500 to 600 BHN. This steel is used for making rock drills, punches, dies, railway rails clutch discs, circular saws, leaf springs, machine chisels, music wires,

Steel containing 0.90 to 1.00% carbon is also known as high carbon tool steel and it possesses hardness of 550-600 BHN. Such steel is used for making punches, dies, springs keys and shear blades.

Steel containing 1.0 to 1.1 % C is used for making railway springs, mandrels, taps, balls, pins, tools, thread metal dies.

Steel containing 1.1 to 1.2% C is used for making taps, twist drills, thread dies, knives.

Steel containing 1.2 to 1.3% carbon is used for making files, reamers Files, dies for wire drawing, broaches, saws for cutting steel, tools for turning chilled iron.

Cutting tool materials imply the materials from which various lathe tools or other cutting tools are made. The best tool material to use for a certain job is the one that will produce the machined part at the lowest cost. To perform good during cutting, the tool material should possess the following properties for its proper functioning.

1. A low coefficient of friction between tool material and chip material.
2. Ability to resist softening at high temperature.
3. Ability to absorb shocks without permanent deformation.
4. Sufficient toughness to resist fracture and bear cutting stresses.
5. Strength to resist disintegration of fine cutting edge and also to withstand the stresses developed, during cutting, in the weakest part of the tool.
6. High hardness that means tool must be harder than the material being cut.

According to Indian standard IS 1570-1961, plain carbon steels are designated by the alphabet 'C' followed by numerals which indicate the average percentage of carbon in it. For example C40 means a plain carbon steel containing 0.35% to 0.45% C (0.40% on average), although other elements like manganese may be present. In addition to the percentage of carbon, some other specification may include e.g. C55Mn75 means the carbon content lies between 0.50% to 0.60% and the manganese content lies between 0.60 to 0.90%. It may be noted that only average contents are specified in such designation of steel.

4.3.5.3 Alloy steel

For improving the properties of ordinary steel, certain alloying elements are added in it in sufficient amounts. The most common alloying elements added to steel are chromium, nickel, manganese, silicon, vanadium, molybdenum, tungsten, phosphorus, copper, that the titanium, zirconium, cobalt, columbium, and aluminium. Each of these elements induces certain qualities in steels to which it is added. They may be used separately or in combination to produce desired characteristics in the steel. The main purpose of alloying element in steel is to improve machinability, elasticity, hardness, case hardening, cutting ability, toughness, wear resistance, tensile strength, corrosion resistance, and ability to retain shape at high temperature, ability to resist distortion at elevated temperature and to impart a fine grain size to steel. Like carbon, a number of alloying elements are soluble to produce alloys with improved strength, ductility, and toughness. Also carbon, besides forming an inter-metallic compound with iron, combines with many alloying elements and form alloy carbides. These alloy carbides as well as iron-alloy carbides are usually hard and lack in toughness. Some

alloying elements are added to prevent or restrict grain growth. Aluminium is considered the most effective in this respect. Others are zirconium, vanadium, chromium, and titanium. The addition of alloying elements almost always affects the austenite-ferrite transformation mechanism. Some alloying elements lower and some raise the critical temperature. The compositional and structural changes produced by alloying elements change and improve the physical, mechanical and processing properties of steel.

4.3.5.4 Effect of alloying elements in steel

The chief alloying elements used in steel are nickel, chromium, molybdenum, cobalt, vanadium, manganese, silicon and tungsten. Each of these elements possesses certain qualities upon the steel to which it is added. These elements may be used separately or in combination to produce the desired characteristic in steel. Following are the effects of alloying elements on steel.

1. **Nickel.** Steels contain 2 to 5% nickel and from 0.1 to 0.5% carbon increase its strength and toughness. In this range, nickel contributes great tensile strength, yield strength, toughness and forming properties and hardness with high elastic limit, good ductility and good resistance to corrosion. An alloy containing 25% nickel possesses maximum toughness and offers the greatest resistance to rusting, corrosion and burning at high temperature. It has proved beneficial in the manufacture of boiler tubes, valves for use with superheated steam, valves for I.C. engines and sparking plugs for petrol engines. A nickel steel alloy containing 36% of nickel is known as invar. It has nearly zero coefficient of expansion. Therefore, it is in great demand for making measuring instruments for everyday use.
2. **Chromium.** It improves corrosion resistance (about 12 to 18% addition). It increases tensile strength, hardness, wear resistance and heat resistance. It provides stainless property in steel. It decreases malleability of steel. It is used in steels as an alloying element to combine hardness with high strength and high elastic limit. It also imparts corrosion resisting properties to steel. The most common chrome steels contain from 0.5 to 2% chromium and 0.1 to 1.5% carbon. The chrome steel is used for balls, rollers and races for bearings. A Nickel-Chrome steel containing 3.25% nickel, 1.5% chromium and 0.25% carbon is much used for armour plates. Chrome nickel steel is extensively used for motor car crank shafts, axles and gears requiring great strength and hardness.
3. **Tungsten.** It increases hardness, wear resistance, shocks resistance and magnetic reluctance. It increases ability to retain hardness and toughness at high temperature. It prohibits grain growth and increases wear resistance, shock resistance, toughness, and the depth of hardening of quenched steel. The principal uses of tungsten steels are for cutting tools, dies, valves, taps and permanent magnets.
4. **Vanadium.** It improves tensile strength, elastic limit, ductility, fatigue resistance, shock resistance and response to heat treatment. It also acts as a degasser when added to molten metal. It aids in obtaining a fine grain structure in tool steel. The addition of a very small amount of vanadium (less than 0.2%) produces a marked increase in tensile strength and elastic limit in low and medium carbon steels without a loss of ductility. The chrome- vanadium steel containing about 0.5 to 1.5% chromium, 0.15 to 0.3% vanadium and 0.13 to 1.1% carbon have extremely good tensile strength, elastic limit, endurance limit and ductility. These steels are frequently used for parts such as springs, shafts, gears, pins and many drop forged parts.

5. **Molybdenum.** A very small quantity (0.15 to 0.30%) of molybdenum is generally used with chromium and manganese (0.5 to 0.8%) to make molybdenum steel. It increases hardness, wear resistance, thermal resistance. When added with nickel, it improves corrosion resistance. It counteracts tendency towards temper brittleness. It makes steel tough at various hardness levels. It acts as a grain growth inhibitor when steels are heated to high temperatures. Molybdenum steels possesses hardness, wear resistance, thermal resistance and extra tensile strength. It is used for air-plane fuselage and automobile parts. It can replace tungsten in high speed steels.
6. **Cobalt. W**hen added to steel, it refines the graphite and pearlite and acts as a grain refiner. It improves hardness, toughness, tensile strength and thermal resistance.
7. **Titanium.** It acts as a good deoxidizer and promotes grain growth. It prevents formation of austenite in high chromium steels. It is the strongest carbide former. It is used to fix carbon in stainless steels and thus prevents the precipitation of chromium carbide.
8. **Aluminium.** It is used as a deoxidizer. If present in an amount of about 1 %, it helps promoting nitriding.
9. **Copper.** It improves resistance to corrosion. It increases strength. More than 0.6 per cent copper for precipitation.
10. **Silicon.** It improves magnetic permeability and decreases hysteresis losses. It decreases weldability and forgeability. It is also added as a deoxidizer during casting of ingots. It takes care of oxygen present in steel by forming SiO_2. Silicon steels behave like nickel steels. These steels have a high elastic limit as compared to ordinary carbon steel. Silicon steels containing from 1 to 2% silicon and 0.1 to 0.4% carbon and other alloying elements are used for electrical machinery, valves in I.C. engines, springs and corrosion resisting materials.
11. **Manganese.** It improves the strength of the steel in both the hot rolled and heat treated condition. The manganese alloy steels containing over 1.5% manganese with a carbon range of 0.40 to 0.55% are used extensively in gears, axles, shafts and other parts where high strength combined with fair ductility is required. The principal use of manganese steel is in machinery parts subjected to severe wear. These steels are all cast and ground to finish.
12. **Carbon.** It increases tensile strength and hardness. It decreases ductility and weldability. It affects the melting point.

4.3.5.5 Free cutting steel

The important features of free cutting steels are their high machinability and high quality surface finish after finishing. These properties are due to higher sulphur and phosphorus. Sulphur exists in the form of manganese sulphide (MnS) which forms inclusions in steel. These inclusions promote the formation of discontinuous chips and also reduce friction on the surface being machined so produces good surface finish easily. Phosphorus is dissolved in the ferrite and increases hardness and brittleness. Lead up to 0.35% can be added to improve the machinability of steel. These have high sulphur content present in form of manganese sulphide inclusions causing the chips to break short on machining. Mn and P make steel hardened and brittle. Lead (0.2% to 0.35%) is sometimes added to steel improving machinability properties of steel. This consists of three Bessemer grades B1111, B1112, B1113 which differ in sulphur content and the sulphurised steels from C1108 to C1151. The tool life achieved in machining

free cutting steels is from 2 to 2.5 times higher than when carbon steels of the same carbon content. However, it must be noted that free cutting steels have lower dynamic strength characteristics and are more susceptible to corrosion. Free cutting steels are frequently supplied in the cold drawn or work hardened form. These cold drawn steels have a high tensile strength and hardness but less ductile when compared to other kind of steels.

Applications of free cutting steel

These steels are used for manufacturing axles, bolts, screws, nuts, special duty shafts, connecting rods, small and medium forgings, cold upset wires and rods, solid turbine rotors, rotor and gear shaft, armature, key stock, forks and anchor bolts screw stock, spring clips, tubing, pipes, light weight rails, concrete reinforcing etc.

4.3.5.6 Nickel steel

The percentage of Nickel varies from 2 to 45 in steel. Steel having 2% Ni makes steel more suitable for rivets, boiler plates, bolts and gears etc. Steel having Ni from 0.3 to 5% raises elastic limit and improves toughness. Steel containing Nickel has very high tensile strength. Steel having 25% Ni makes it stainless and might be used for I.C. engine turbine blade etc. If Ni is present up to 27%, it makes the steel non-magnetic and non-corrodible. Invar (Ni 36%) and super-invar (Ni 31%) are the popular materials for least coefficient of expansion and are used for measuring instruments, surveyor tapes and clock pendulums. Steel having 45% Ni steel possesses extension equal to that of glass, a property very import making links between the two materials i.e. in electronic valves and bulbs.

4.3.5.7 Vanadium steel

Vanadium when added even in small proportion to an ordinary low carbon increases significantly its elastic limit and fatigue resistance property. Vanadium makes steel strong and tough. When vanadium is added up to 0.25%, the elastic limit of the steel is raised by 50% can resist high alternating stresses and severe shocks.

Applications

1. It is widely used for making tools.
2. It can also be used for shafts, springs, gears, steering knuckles and drop forged parts

4.3.5.8 Manganese steel

Manganese when added in steel between 1.0 to 1.5% makes it stronger and tougher. Manganese between 1.5 to 5% in steel makes it harder and more brittle. 11 to 14% manganese in steel with carbon 0.8 to 1.5% makes it very hard, tough, non-magnetic and possesses considerably high tensile strength. Manganese steel may be forged easily but it is difficult to machine and hence it is usually ground. It is weldable and for welding it, a nickel manganese welding rod is used.

Applications

1. Because of work hardening, it is suitable for jaws of stone and ore crushers, grinding plants, tramway and railway points and crossing etc.
2. Manganese steel in the form of bars is now widely used for screening coke.
3. It is also used for helmets and shields.
4. It is used for agricultural implements such as shovels etc.

4.3.5.9 Tungsten Steel

Tungsten when added to steel improves its magnetic properties and hardenability. When tungsten is added to an extent of 6% to high carbon steel, it retains the magnetic properties to high degree and produce field more intense than ordinary steel. Steel having 8% tungsten gives sufficient hardness to it to scratch even glass.

Applications

It is used for making permanent magnets and high speed cutting tools.

4.3.5.10 Silicon steel

Silicon addition improves the electrical properties of steel. It also increases fatigue strength and ductility.

Applications

1. Steel with

   Mn = 1 %, Si = 2% and C = 0.4 to 0.6%

   has very high elastic limit and is used for springs.
2. Steel containing 5 to 7% silicon

   retains its hardness and resistance to oxidation at high temperature. It is used for making internal combustion engines.
3. Steel possessing 13% Si has a very high corrosion resistance and it can be used in chemical industrial applications.
4. Steel possessing 1% Si and up to 0.95% Mn is suitable for structural purposes.

4.3.5.11 Magnetic steels

Steels having 15 to 40% Co, 0.4 to 1 % C, 1.5 to 9% Cr, 0-10% W and remaining Fe possesses very good magnetic properties. High Cobalt steels, when correctly heat treated, are frequently used in the making of permanent magnets for magnetos, loud speakers and other electrical machines. An important permanent magnet alloy called Alnico contains approximately 60% Iron, 20% Nickel, 8% Cobalt and 12% Aluminium. This alloy cannot be forged and is used as a casting hardened by precipitation heat treatment.

4.3.5.12 Heat resisting steels

Heat resisting steels are practically suitable for working at even very high temperatures. Such steels must resist the influences which lead to failure of ordinary steels when put to work under high temperatures. Alloy steel containing 23-30% chromium with less than 0.35% C are mainly used to impart heat resisting service in the temperature range between 815-1150 °C. The furnace parts and annealing boxes are generally made by this steel. These steels are particularly suitable for working at high temperatures and are thus stable at high temperatures. A steel containing chromium, nickel and tungsten, with the carbon content suitably controlled provide useful combination of non-scaling and strength retaining properties at high temperature. Such steels can work satisfactory up to 700°C and contains 0.15% C, 0.5 to 2 % Si, 0.5% Mn, 1.0 to 6%, Cr and 0.5%. Mo.

Applications

These are used in nuclear power plant, furnaces, supersonic aircrafts, missiles, annealing boxes etc.

4.3.5.13 Spring steels

Spring steels are used for the making springs. Various types of these steel along with their composition and uses are discussed as under.

(*i*) **Carbon-manganese spring steels.** This type of steel contains

C = 0.45 to 0.6, Si = 0.1 to 0.35% and Mn = 0.5 to 1.0%.

These steels are quenched and tempered up to 350 BHN. They are widely used for laminated springs for railway and general purposes.

(*ii*) **Hyper-eutectoid spring steels.** This type of steel contains

C = 0.9 to 1.2%, 0.3% (max) and Mn = 0.45 to 0.70%.

These steels are oil quenched and tempered at low temperature. This type of steel is used for volute and helical springs.

(*iii*) **Silicon-manganese spring steels.** This type of steel contains

C = 0.3 to 0.62%, Si = 1.5 to 2% and Mn = 0.6 to 1 %.

These steels are hardened and tempered. This type of steel is used for the manufacturing of railway and road springs generally.

4.3.5.14 Structural steels

Structural steels possess high strength and toughness, resistance to softening at elevated temperatures and enough resistance to corrosion. In addition, they should possess weldability, workability and high hardenability. The principal alloying elements in structural steels are chromium, nickel and manganese. These steels has various applications which are given as under:

Applications

They are used for structural members of bridges, buildings, rail road, cars etc. They are also used for manufacturing components subjected to static and dynamic loads. These components include valves, pins, studs, gears, clutches, bushes, shafts etc.

4.3.5.15 Stainless steel

Stainless steel contains chromium together with nickel as alloy and rest is iron. It has been defined as that steel which when correctly heat treated and finished, resists oxidation and corrosive attack from most corrosive media. Stainless steel surface is responsible for corrosion resistance. Minimum chromium content of 12% is required for the film's formation, and 18% is sufficient to resist the most severe atmospheric corrosive conditions. Their principal alloying element is chromium while some other elements like nickel, manganese etc. can also be present in small amounts. Addition of nickel improves ductility and imparts strength. Corrosion resistance to stainless steels increases with increase in nickel content against neutral chloride solution and weakly oxidizing acids. Addition of molybdenum improves its resistance to sulphuric, sulphurous and organic acids. Addition of manganese increases hot workability of these steels.

Steels having 15 to 20% Ni and about 0.1 % carbon possesses great strength and toughness and extremely good resistance to corrosion. Such steels are called stainless steels. Another type of stainless steel containing 11 to 14% chromium and about 0.35% carbon is used for cutlery, surgical and dental instruments and other purposes where hard edges are required. Maximum resistance to corrosion is obtained when this steel is ground and polished after heat-treating.

A **steel containing 18% chromium and 8% nickel is widely used** and is commonly referred to as 18/8 steel. Stainless steel is highly resistance to corrosion and oxidation. It can be classified into three major categories according to the type of micro structures.

General Properties of Stainless Steels

It possesses wide range of strength and hardness, high ductility, formability, high corrosion resistance, good creep resistance, good thermal conductivity, good machinability, good weldability, high hot, cold workability, high resistance to scaling and oxidation at elevated temperatures, excellent surface appearance and finish.

Classification of Stainless Steel

On basis of their structure, stainless steels are classified as follow:

1. Martensitic stainless steels
2. Ferritic stainless steels
3. Austenitic stainless steels.

These types of stainless steel are discussed as under.

Martensitic Stainless Steels

These steels contain 12 to 16% chromium and 0.1 to 1.2 per cent carbon. The structure consists of hard martensite phase after hardening. The general utility chromium stainless steel with 12% chromium and 0.15% carbon are ferromagnetic and air hardening. It is very hard and possesses high strain and high corrosion resistance properties.

Applications

Stainless steels containing 12 to 14% chromium and 0.3% carbon are extensively used for table cutlery, tools and equipments etc. Stainless steels containing 16-18% chromium and 0.2% carbon are used as springs, ball bearing, valves, knife blades and instruments under high temperature and corrosive conditions. These steels are generally used for making utensils, surgical and dental instruments, and springs of high temperature operations, ball valves and toilet seats.

Ferritic Stainless Steels

Ferritic stainless steels are non hardenable and contain 16 to 30% chromium and 0.08 to 0.2 per cent carbon. Structure of these steel consists of ferrite phase which cannot be hardened by heat treatment. They have very low carbon and possess considerable ductility, ability to be worked hot or cold, excellent corrosion resistance and are relatively in expensive. They are always magnetic and retain their basic microstructure up to the melting point.

Applications

These are extensively used for kitchen equipment, diary machinery interior decorative work, automobile trimmings, chemical engineering industry, stainless steel sinks, food containers, refrigerator parts, beer barrels, automobile trimming etc. These are also used as high temperature furnace parts when chromium content is high.

Austenitic Stainless Steel

Addition of substantial quantities of Ni to high Cr alloys gives rise to, austenitic steel. It has good resistance to many acids (even hot or cold nitric acid). Slight amount of W and Mo are added in such steels to increase its strength at elevated temperatures. This steel

contains 16 to 24% Cr, 8 to 22% Ni and less than 0.2% C. Addition of nickel stabilizes austenite, and hence the structure of these steels consists of austenite at room temperature. A steel containing 18% Cr and 8% Ni is very widely used and is commonly referred to as 18/8 stainless steel. These steels do not harden by heat treatment but can be rolled hard. These steels possess a brilliant luster when polished. These are highly resistant to many acids even nitric acids. The heat conductivity of steel is low, about 5% that of copper. Tungsten and molybdenum are added to increase the strength at elevated temperatures, silicon and aluminium to improve the resistance to scaling and selenium and sulphur are added to improve machinability. This steel is easily weldable. After welding, it is susceptible to corrosive attack in the area adjacent to the weld.

Applications

It is used for making heat exchangers, conveyors chains, furnaces, spokes, brewery, dairy and chemical industrial components, cutlery parts, surgical and dental instruments, household appliances such as kitchen utensils, sinks and saucepans. These are also used in making components in power stations, especially in nuclear power stations, steam pipes, boiler tubes, radiator and super heater tubes.

4.3.5.16 High speed steels

High Speed Steels (HSS) have been given this name due to the fact that these steels may be operated as cutting tools at much higher speeds that are possible with plain carbon tool steel. High speed steels cutting tools operate at cutting speed 2 to 3 times higher than for High carbon steels. At higher cutting speeds, sufficient heat may be developed during the cutting process. This heat causes the cutting edge of the tool to reach a high heat (red heat). This heat softens the carbon tool steel and thus the tool will not work efficiently for a longer period. These steels have the property of retaining their hardness even when heated to red heat. High hardness at elevated temperatures is developed by addition of elements such as tungsten, chromium vanadium to high carbon steels. These steel are generally used for making lathe cutting tools, planner cutting tools, shaper cutting tools, slotting cutting tools, drills, reamers, broaches, milling cutter and punches. There are four general types of high speed steels used in machine shop.

1. High speed steel (18:4:1)

High speed steels (HSS) are most commonly operated as cutting tools at much higher speed i.e. twice or thrice where as tool steel. It is the most common kind of cutting tool. It contains 18% tungsten, 4% chromium and 1 % vanadium, 0.8 carbon and remaining iron. It is considered to be one of the best of all purpose tool steels. This brand of high speed steel is used for machining operations on steel and non-ferrous materials. This is generally used for lathe, planer and shaper tools, drills, millings cutters, punches etc.

2. Molybdenum based high speed steel

It contains 6% Mo, 6% W, 4% Cr, 2% V, 0.8% C and remaining Fe. It has excellent toughness and cutting ability. Molybdenum high speed steels are cheaper than other types of steels and are particularly used for drilling and tapping tools. These steels are also used for making rough cutting tools, lathe tools and various kinds of milling cutters.

3. Cobalt based high speed steel

It contains 1 to 12% Co, 20% W, 4% Cr, 2% V, 0.8 carbon and remaining iron. This is also known as super high speed steel, because cutting tool made of this steel can be operated

at much higher speeds in comparison to high speed steel of 18:4:1 kind. In this steel, cobalt is added from 2 to 15 per cent in order to increase the cutting efficiency especially at high temperature. Cobalt high speed steel generally contains 20% W, 4% Cr, 2% V and 12% Co and remaining Fe. Since the cost of this steel is more, therefore, it is principally used for making cutting tools for heavy operations which impose high pressure and temperature on the tool. It is extensively used for making high production tools of heavy work for high production lathe, planer, shaper, milling and boring machine.

4. Vanadium High Speed Steel

Generally, this steel contains more than 1% V and 0.70% C. This steel possesses better abrasive resistance in comparison to normal HSS type steel. It is preferred for machining materials which are highly difficult to machine by conventional means. These steels cutting tools are close competitors of carbides cutting tools such as drills, reamers, milling cutters etc. In addition to having heat resistance properties of high speed steels possesses desirable properties of high hardness, high compressive strength and outstanding wear resistance.

4.3.5.17 Availability of steel in market

Steel are available in market in various rolled forms like sheets, plates, strips, rods, beams, channels, angles, tees etc. The common structural shapes for market form of supply are reflected in Fig. 4.5. Steels are generally identified, coded and designated according to suitable standards by a group of symbols indicating the important characteristics.

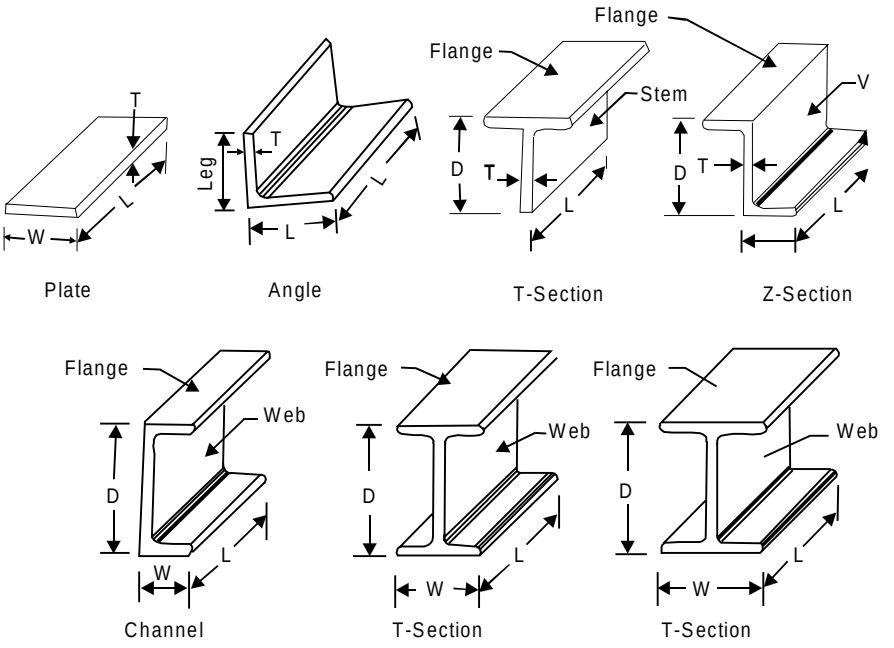


Fig. 4.5 Market forms of steel structure shapes

4.3.5.18 Designation of steels

Bureau of Indian Standards (BIS) designates the various grades of steels by a system of codification which bears direct relationship with the important characteristics of steel such as

tensile strength, chemical composition. physical and surface conditions. According to this method a particular grade designation would be applicable to certain steel only. Hence steel may be designated by a group of symbols indicating the important characteristics.

(*i*) 1025. Indicates C-25 which is plain carbon steel,

(*ii*) 1112. It is a free cutting steel having percentage

C = 0.13 Max.
Mn = 0.7 – 1.0 %
P = 0.07 – 0.12 %
S = 0.16 – 0.23%

(*iii*) 4145. It is Cr-Mo – steel having percentage

C = 0.33 – 0.38%
Mn = 0.7 – 0.9%
P or S = 3.025%
Si = 0.2 – 0.35%
Cr = 0.81 – 1.1 %
Mo = 0.18 – 0.25%

(*iv*) 8650. It is Ni-Cr-Mo alloy steel having percentages

Ni = 0.4 – 0.7%
Cr = 0.4 – 0.6%
Mo = 0.15 – 0.25%

(*v*) 3145. It is a Ni-Cr steel having

Ni = 0.3 – 0.35%
Cr = 0.4 – 0.5%

(*vi*) 2330. It is a Ni-steel having percentages

C = 0.28 – 0.33%
S = 0.04%
Mn = 0.5%
Si = 0.02 – 0.35 %
Ni = 3.25 – 3.75%

(*vii*) 5150 It is a Cr-Steel

Following symbol recommended to be used to indicate heat treatment given to steel and is to be suffixed at the end of normal symbol of steel.

(1)	Annealed and softened	*a*
(2)	Case carburized	*c*
(3)	Hard, drawn, cold reduced	*d*
(4)	Hot rolled	*h*
(5)	Normalized	*n*
(6)	Spherodised	*0*

(7)	Patented	*p*
(8)	Hardened and Tempered	*q*
(9)	Stress relieved	*s*
(10)	Tempered	*t*

Steel Quality

Following symbols should be recommended to be suffixed with the normal steel symbol to indicate the steel quality

(1)	Non-ageing quality	A
(2)	Stabilizing against stress corrosion and inter-annular attack	E
(3)	Control cooled ensure freedom from flakes	L
(4)	Fully-killed (deoxidized)	D
(5)	Semi-killed	D2
(6)	Rimming quality	R
(7)	Grain size controlled	G
(8)	Hardenability controlled	H
(9)	Inclusion controlled	I
(10)	Structural homogeneity guaranteed by macro- structure test	M

Carbon Tool Steel (Annealed)

Carbon tool steel in annealed condition is explained as below with designation and uses.

C-60	Spindles for machine tools, coupling, crank shaft axles and pinions.
C-65	Small washers and thin stamped parts.
C- 70	Buffer spring shock absorbers.
C- 75	Light flat, springs formed from annealed stock.
C-75-C-85	Flat and coils springs for automobiles and railway vehicles.
C-50 to C-113	Springs made from small flat section.

Plain Carbon Structural Steel

Designation and Uses

St-42	For bridge and building construction, railway rolling stock, screw spikes and oil well castings.
St-44	Pressure vessels, fasteners, value fittings for compressed gas cylinders and railway rolling stock.
St-47	For railway rolling stock, pressure parts of marine and land boilers and rivets for air receivers.
St-50	For mines, forgings of marine and engine parts.
St-52-54	For railway wheels, electric tramways cars.

4.4 QUESTIONS

1. How are engineering materials classified?

2. How ferrous metals differ from non-ferrous metals?

3. State the name of important iron ores.

4. How cast iron differs from steel?

5. Write short notes on :

(*i*) Pig iron

(*ii*) Grey cast iron

(*iii*) White cast iron

(*iv*) Ductile cast iron

(*v*) Malleable cast iron.

6. Discuss in brief the effect of impurities in cast iron.

7. What is wrought iron? Discuss in brief its chemical composition, properties and applications.

8. What are plain carbon steels? Discuss in brief the classification of plain carbon steels and also state few applications of different plain carbon steels.

9. What are alloy steels? Discuss in brief the effects of alloying elements on steel.

10. How are alloy steels classified?

11. Write short notes on:

(*i*) Stainless steel

(*ii*) High speed steel

(*iii*) Designation of steels.

5
CHAPTER

NON-FERROUS MATERIALS

5.1 INTRODUCTION

Engineering materials can be categorized into metals and alloys, ceramic materials, organic polymers, composites and semiconductors. There are large numbers of engineering materials available in the universe such as metals (both ferrous and non-ferrous) and non metals (leather, rubber, asbestos, plastic, ceramics, organic polymers, composites and semi conductor). The elements of tools, machines and equipments should be made of such a material which has properties suitable for the conditions of operation e.g components of ships and naval work requires corrosion resistance against sea water. It is therefore important to know what non ferrous metals are available in the universe, what their characteristics are like strength, hardness, availability and costs, and how they can be processed economically to get the desired product. In addition to this, a product designer, tool designer, equipment design engineer and system design engineer should always be familiar with various kinds of engineering materials including non ferrous metals, their properties, and applications to meet the functional requirements of the design product. They must understand all the effects which the manufacturing processes and heat treatment have on the properties of the non ferrous metals. The non ferrous metals and their alloys have tremendous applications for manufacturing industrial products.

The basic knowledge of non-ferrous metals and their properties is of great significance for a design and manufacturing engineer. Non-ferrous metals contain metals other than iron as their main constituents such as aluminium, copper, zinc, magnesium, lead, tin, nickel and their alloys and non-metallic materials. Various non-ferrous alloys are copper base (brass, bronze), aluminium base alloys (duralumin, Y-alloy, hindalium, magnalium), nickel alloys (inconel, monel and ni-chrome), tin base alloys (bearing or antifriction alloys). The non-ferrous metals are used for the following purposes namely resistance to corrosion, special electrical and magnetic properties, softness, facility of cold working, fusibility, ease of casting, good formability, low density and attractive color. The properties and uses of various non-ferrous metals are given in the following articles.

5.2 ALUMINIUM

It is a white metal produced by electrical processes from the oxide (alumina), which is prepared from a clay mineral called bauxite. Bauxite is hydrated aluminium oxide. The chief

impurities are oxide, silica, clay and titanium oxide. It is found in India in the states of Bihar and Madhya Pradesh.

Manufacture

The bauxite is purified and then dissolved in fused cryolite (double fluoride of aluminium and sodium). The aluminium is then separated from this solution by electrolysis at about 910°C.

Properties

Pure aluminium has silvery color and lusture. It is ductile, malleable and very good conductor of heat and electricity. It has a very high resistance to corrosion than the ordinary steel. Its specific gravity is 2.7 and melting point is 658°C. Its tensile strength varies from 95 to 157 MN/m^2. In proportion to its weight it is quite strong. In its pure state the metal would be weak and soft for most purposes, but when mixed with small amounts of other alloys, it becomes hard and rigid. It may be blanked, formed, drawn, turned, cast, forged and die cast. Its good electrical conductivity is an important property and is broadly used for overhead cables. It forms useful alloys with iron, copper, zinc and other metals.

Applications

It is mainly used in aircraft and automobile parts where saving of weight is an advantage. The high resistance to corrosion and its non-toxicity make it a useful metal for cooking utensils under ordinary conditions. Aluminium metal of high purity has got high reflecting power in the form of sheets and is, therefore, widely used for reflectors, mirrors and telescopes. It is used in making furniture, doors and window components, rail road, trolley cars, automobile bodies and pistons, electrical cables, rivets, kitchen utensils and collapsible tubes for pastes. Aluminium foil is used as silver paper for food packing etc. In a finely divided flake form, aluminium is employed as a pigment in paint. It is a cheap and very important non ferrous metal used for making cooking utensils.

5.2.1 Aluminium alloys

The aluminium may be easily alloyed with other elements like copper, magnesium, zinc, manganese, silicon and nickel to improve various properties. The addition of small quantities of alloying elements into other metals helps to converts the soft and weak metal into hard and strong metal, while still retaining its light weight. Various aluminium alloys are

1. Duralumin,
2. Y-alloy,
3. Magnalium and
4. Hindalium

These alloys are discussed as below:

5.2.2 Duralumin

It is an important wrought alloy. Its composition contains following chemical contents.

Copper = 3.5-4.5%
Manganese = 0.4-0.7%
Magnesium = 0.4-0.7%
Aluminium = 94%

Properties

Duralumin can be very easily forged, casted and worked because it possesses low melting point. It has high tensile strength, comparable with mild steel combined with the characteristics lightness of Al. It however possesses low corrosion resistance and high electrical conductivity. This alloy possesses higher strength after heat treatment and age hardening. After working, if this alloy is age hardened for 3 or 4 days. This phenomenon is known as age hardening. It hardens spontaneously when exposed to room temperature. This alloy is soft enough for a workable period after it has been quenched. It is light in weight as compared to its strength in comparison to other metals. It can be easily hot worked at a temperature of 500°C. However after forging and annealing, it can also be cold worked.

Applications

Duralumin is used in the wrought conditions for forging, stamping, bars, sheets, tubes, bolts, and rivets. Due to its higher strength and lighter weight, this alloy is widely used in automobile and aircraft components. To improve the strength of duralumin sheet, a thin film of Al is rolled along with this sheet. Such combined sheets are widely used in air-craft industries. It is also employed in surgical and orthopedic work, non-magnetic work and measuring instrument parts constructing work.

5.2.3 Y -alloy

Y-Alloy is also called copper-aluminium alloy. The addition of copper to pure aluminium increases its strength and machinability. Its composition contains following chemical contents.

Copper	=	3.5-4.5%
Manganese	=	1.2-1.7%
Nickel	=	1.8-2.3%
Silicon, magnesium, iron	=	0.6% each
Aluminium	=	92.5%.

Properties

The addition of copper in aluminium increases its strength and machinability. Y-alloy can be easily cast and hot worked. Like duralumin, this alloy is heat treated and age hardened. The age-hardening process of Y-alloy is carried out at room temperature for about five days.

Applications

Y-Alloy is mainly used for cast purposes, but it can also be used for forged components like duralumin. Since Y -alloy has better strength than duralumin at high temperatures, therefore it is much used in aircraft engines for cylinder heads, pistons, cylinder heads, crank cases of internal combustion engines die casting, pump rods etc.

5.2.4. Magnalium

Magnalium is an alloy of aluminium, magnesium, copper, nickel and tin etc. It contains

Al	=	85 to 95%,	Cu	=	0 to 25%,	Mg	=	1 to 5%,
Ni	=	0 to 1.2%,	Sn	=	0 to 3%,	Fe	=	0 to 0.9%,
Mn	=	0 to 0.03%,	Si	=	0.2 to 0.6%.			

It is made by melting the aluminium with 2-10% magnesium in a vacuum and then cooling it in a vacuum or under a pressure of 100 to 200 atmospheres.

Properties

Magnalium is light in weight and brittle. This alloy possesses poor castability and good machinability. It can be easily welded.

Applications

Due to its light weight and good mechanical properties, it is mainly used for making aircraft and automobile components.

5.2.5 Hindalium

Hindalium is a common trade name of aluminium alloy. It is an alloy of aluminium, magnesium, manganese, chromium and silicon etc. In India, it is produced by Hindustan Aluminium Corporation Ltd., Renukoot (U.P.). Hindalium is commonly produced as a rolled product in 16 gauges. Utensils manufactured by this alloys are strong and hard, easily cleaned, low cost than stainless steels, having fine finish, having good scratch resistance, do not absorb much heat etc.

Applications

Hindalium is mainly used for manufacturing anodized utensil. Utensils manufactured by this alloys are strong and hard, easily cleaned, low cost than stainless steels, having fine finish, having good scratch resistance, do not absorb much heat etc.

5.3 COPPER

Copper is one of the most widely used non-ferrous metals in industry. It is extracted from ores of copper such as copper glance, copper pyrites, melachite and azurite. Copper ores are found in the state of Sikkim and Bihar of India and Bharma.

Manufacture

Copper ore is first ground and then smelted in a reverberatory or small blast furnace for producing an impure alloy. Then the air is blown through the molten metal to remove sulphur and iron contamination to obtain blister copper in the converter. Copper is then refined further using electrolysis processes.

Properties

Pure copper is soft, malleable and ductile metal with a reddish-brown appearance. It is a good conductor of electricity. It is non-corrosive under ordinary conditions and resists weather very effectively. Its tensile strength varies from 300 to 470 MN/m2 and melting point is 1084°C. It is one of the best conductors of heat and it is highly resistant to corrosion. This non ferrous metal can withstand severe bending and forging without failure. It does not cast well. If copper is heated to red heat and cooled slowly it becomes brittle, but if cooled rapidly it becomes soft, malleable and ductile. It can be welded at red heat.

Applications

Copper is mainly used in making electric cables and wires for electric machinery, motor winding, electric conducting appliances, and electroplating etc. It can be easily forged, casted, rolled and drawn into wires. Copper in the form of tubes is used widely in heat transfer work

mechanical engineering field. It is used for household utensils. It is also used in production of boilers, condensers, roofing etc. It is used for making useful alloys with tin, zinc, nickel and aluminium. It is used to form alloys like brass, bronze and gun metal. Alloys of copper are made by alloying it with zinc, tin, and lead and these find wide range of applications. Brass, which is an alloy of copper and zinc, finds applications in utensils, household fittings, decorative objects, etc. Bronze is an alloy of copper and tin and possesses very good corrosion resistance. It is used in making valves and bearings. Brass and bronze can be machined at high speeds to fine surface finish.

The following copper alloys are important

1. Copper-zinc alloys (Brasses)
2. Copper-tin alloys (Bronzes)

5.3.1 Brasses

Brasses are widely used alloy of copper (main constituent) and zinc. They also contain small amounts of lead or tin or aluminium. The most commonly used copper-zinc alloy is brass. There are various types of brasses, depending upon the proportion of copper and zinc. The fundamental a binary alloy comprises 50% copper and 50% zinc. By adding small quantities of other elements, properties of brass may be greatly changed. For example addition of lead (1 to 2%) improves the machining quality of brass. It has a greater-strength than that of copper, but has a lower thermal and electrical conductivity. Brasses alloys are very resistant to atmospheric corrosion and can be easily soldered. They can be easily fabricated by processes like spinning and can also be electroplated with metals like nickel and chromium. Some of common phases of brass are discussed as under.

Alpha Phase

If the copper crystal structure is face centered cubic (FCC), there will be up to 36% of zinc. This solid solution is known as alpha brass. It has good mechanical properties, good corrosion resistance but it possesses lower electrical conductivity than copper.

Beta Phase

If the amount of zinc increases beyond 36%, beta brass will appear in the microstructure of the slowly cooled brass. This has body centered cubic structure (BCC). This phase is hard but quite tough at room temperature.

Gamma Phase

When zinc content is increased in brass beyond 45%, then gamma phase is appeared in its structure. This structure is extremely brittle, rendering an alloy which makes it unsuitable for general engineering purposes. The various types of brasses are discussed as under.

5.3.1.1 Red Brass

Red brass is an important material used for heat conducting purposes. Itcontains

$$\text{Cu} = 85\%$$

$$\text{Zn} = 15\%.$$

Properties

Red brass is having excellent corrosion resistance and workability. It possesses tensile strength ranging from 27-31 kg/mm 2. Percentage elongation of this brass is 42-48.

Applications

Red brass is mainly utilized for making, heat exchanger tubes, condenser, radiator cores, plumbing pipes, sockets, hardware, etc.

5.3.1.2 Yellow Brass or Muntz Metal

Yellow brass is also known as muntz metal. It contains

Cu = 60%

Zn = 40%

Muntz metal is having high strength and high hot workability. It is having tensile strength 38 Kg/mm^2 (approximately). The percentage elongation of this brass is 45%.

Applications

Yellow brass or muntz metal is suitable for hot working by rolling, extrusion and stamping. It is utilized for making small various components of machine and electrical equipment such as bolts, rods, tubes, valves and fuses. This metal is utilized for making for pump parts, valves, taps, condenser tubes, sheet form for ship sheathing (because of excellent corrosion resistance).

5.3.1.3 Cartridge Brass

It contains 70% Cu and 30% Zn. It is having good combination of strength and ductility. It is having tensile strength between 31-37 kg/mm^2. Percentage elongation of this brass is 55-66%. It is generally processed into rolled sheets. The metal alloy can be easily cold worked using cold working processes such as wire drawing, deep drawing and pressing.

Applications

It is utilized for making for making tubes, automotive radiator cores, hardware fasteners, rivets, springs, plumber accessories and in tube manufacture.

5.3.1.4 Admiralty Brass

It contains

Cu = 71%

Zn = 29%

Sn = 1%

Properties

1. Admiralty brass is highly resistant to corrosion.
2. It is highly resistant to impingement attack of sea water.
3. It is having tensile strength 30 kg/mm^2 (approx.).
4. It can be cold worked
5. It possesses good corrosion resistance to sea water corrosion.
6. The percentage elongation of admiralty brass is 65%.

Applications

Admiralty brass is utilized for making condenser tubes in marine and other installations. It is used for making plates used for ship building. It is utilized also for making bolts, nuts, washers, condenser plant and ship fittings parts, etc.

5.3.1.5 Naval Brass

Navel brass is commonly used for making marine components. It contains

Cu = 59%
Zn = 40%
Sn = 1%

Properties

Properties of naval brass are similar to muntz metal. As 1% zinc is replaced by 1% tin in Muntz metal to make navel brass, corrosion resistance of this material to sea water is significantly improved. The percentage elongation of navel brass is 47% and its tensile strength is 38 kg/mm^2 (approx.).

Applications

Navel brass is commonly utilized for making marine hardware casting, piston rods, propeller shafts, welding rods etc.

5.3.1.6 Manganese Brass

Manganese brass is sometimes also called manganese bronze. It contains

Cu = 60%
Zn = 38%
Mn = 0.5%
Fe = 1.0%
Sn = 0.5%

Properties

Manganese brass possesses sufficient toughness and good corrosion resistance. It is very active in reducing the oxides of other metals.

Applications

Manganese brass is utilized for making hydraulic rams, valves and cylinders, tubes, pump rods, propellers, bolts, nuts etc.

5.3.1.7 Iron Brass or Delta Metal

Iron brass or delta brass contains

Cu = 60%
Zn = 37%
Fe = 3%

Iron brass or delta metal is hard, strong, tough, and having good corrosion resistance. It can be casted easily.

Applications

If corrosion is to be resisted in mild steel, then some amount of iron brass or delta metal is added in mild steel.

5.3.1.8 Gilding Brass

Gilding brass is a very cheap metal for making jewellery, decorative and ornamental products. It generally contains

Cu = 85%
Zn = 15%

Applications

Because of better appearance this metal is commonly used for jewellery, decorative and ornamental work.

5.3.1.9 Free Cutting Brass

Free cutting brass contains

Cu = 57.5%
Zn = 40%
Pb = 2.5%

Free cutting brass is highly machinable and it does not allow bending.

Applications

Free cutting brass is used for making cast, forged or stamped blanks to be used for further machining such as high speed turning and screwing.

5.3.1.10 Lead Brass

Lead brass is also known as cloak brass which contains

Cu = 65%
Zn = 34%
Pb = 1%

Applications

Lead brass or cloak brass is used in making small gears and pinions for clock work.

5.3.2 Bronzes

Bronze is a common alloy of copper and tin. The alloys of copper and tin are generally termed as bronzes. The wide range of composition of these alloys comprise of 75 to 95% copper and 5 to 25% tin.

Properties of bronzes

Bronze has higher strength, better corrosion resistance than brasses. It is comparatively hard and resists surface wear and can be shaped or rolled into wire, rods and sheets very easily. It has antifriction or bearing properties. Bronze is costlier than brass. The tensile strength of bronze increases gradually with the amount of tin, reaching a maximum when tin is about 20%. However the percentage of tin content if increases beyond this amount, the tensile strength decreases very rapidly. Bronze is most ductile when it contains about 5% of tin. As the amount of tin increases about 5%, the ductility gradually decreases and practically disappears with about 20% of tin. Whereas presence of zinc in the bronze increases fluidity of molten metal, strength and ductility.

Some of the common types of bronzes are discussed as under:

5.3.2.1 Phosphor Bronze

When bronze contains phosphorus in very small amount, then phosphor bronze is produced. A common type of phosphor bronze has the following composition.

Cu = 89 to 94%
Sn = 6 to 10%
P = 0.1 to 0.3%

Properties

Tensile strength, ductility, elasticity, soundness of castings, good wearing quality and resistance to fatigue of phosphor bronze increases with increase of phosphorus in bronze. This material possesses good corrosion resistance especially for sea water, so that it is much used for propeller blades. Phosphor bronze of proper composition can be easily casted, forged, drawn, and cold rolled.

Applications

Phosphorus bronze is used making for bolts, electric contact springs, bearings, bushes, gears, ship sheathing, valve parts, propeller blades, worm wheels, gears, nuts for machine lead screws, pump parts, linings and for many other purposes. It is also suitable for making springs and corrosion resistance mine cables.

5.3.2.2 Silicon bronze

Silicon bronze contains

Cu = 96%
Si = 3%
Mn or Zn = 1%

Silicon bronze has good general corrosion resistance of copper combined with higher strength. It can be cast, rolled, stamped, forged and pressed either hot or cold and it can be welded by all the usual methods.

Applications

Silicon bronze is widely used for making boilers, tanks, stoves or where high strength and good corrosion resistance is required. It is used also for making screws, tubing's, pumps etc.

5.3.2.3 Beryllium bronze

Beryllium bronze is a copper base alloy contains

Cu = 97.5%
Br = 2.5%

Beryllium bronze possesses higher tensile strength than other bronzes. It possesses excellent corrosion resistance. It is having high yield point and high fatigue limit. It is having good hot and cold resistance. This can be heat treated by precipitation hardening. It possesses excellent formability in soft condition, and high fatigue and creep resistance in hardened condition. However it involves high cost.

Applications

Beryllium bronze is particularly suitable material for making springs, tubes, diaphragms and electrical contacts, heavy duty electrical switches, cams and bushings. This is used for

springs, heavy duty electrical switches, cams and bushings. Having non-sparking characteristics, it is used for making chisels and hammers using for such conditions where spark might cause explosion. It has a film forming and a soft lubricating property, which makes it more suitable as a bearing metal. Since the wear resistance of beryllium copper is five times that of phosphorous bronze, therefore it is used as a bearing metal in place of phosphor bronze.

5.3.2.4 Manganese bronze

Manganese bronze is an alloy of copper, zinc and little percentage of manganese. The usual composition of this bronze is

Copper = 60%
Zinc = 35%
Manganese = 5%

Manganese bronze is highly resistant to corrosion. It is stronger and harder than phosphor bronze.

Applications

Manganese bronze is mainly used for bushes, plungers, feed pumps, rods etc. Worm gears are frequently made from this bronze.

5.3.2.5 Aluminium Bronze

Aluminium bronze possesses

Cu = 85 to 88%
Al = 8 to 11%
Fe = 3%
Sn = 0.5%

Properties

The aluminium bronze with 8% aluminium possesses very good cold working properties. When iron is added to this metal, its mechanical properties are greatly improved by refining the grain size and improving the ductility. The maximum tensile strength of this alloy is 450 MPa with 11 % aluminium. This material possesses good resistance to corrosion and it is somewhat difficult to cast due to oxidation problem.

Applications

Aluminium bronze is generally used for making fluid connection fittings, gears, propellers, air pumps, bushings, tubes, slide and valves etc. Cams and rollers are commonly produced using this alloy.

5.3.2.6 Bell Metal

Bell metal generally contains

Cu = 66.7%
Sn = 33.3%

Bell metal is very strong. It possesses resistance to corrosion water and atmosphere. It is used to make bells.

5.3.3 Constantan

The composition of constantan is

Cu = 55%

Ni = 45%

Properties

(*i*) Constantan is high specific resistance

(*ii*) Specific resistance is unaffected by temperature variation.

Applications

Constantan is used for accurate resistors like thermo-couples,

(*i*) Wheet-stone bridge,

(*ii*) Low temperature heaters and

(*iii*) Resistances

5.4 NICKEL AND ITS ALLOY

Nickel and its alloys are discussed as under.

5.4.1 Nickel

Nickel is a silvery shining white metal having extremely good response to polish. The most important nickel's ore is iron sulphides which contain about 3% of nickel. About 90% of the total production of nickel is obtained by this source. This ore is mainly found in Canada and Norway.

Manufacture

The ore of Nickel is initially roasted to reduce the sulphur content and then smelted to separate the gangue from it. Matte (impure product of the smelting of sulphide ore especially those of nickel or copper, is known as matte) delivered by the smelting furnace is then put in a Bessemer converter to oxidize the iron. The iron oxide thus combines with a limestone and quartz and form the slag. The Bessemer's matte consists chiefly of copper and nickel sulphides.

Properties

Nickel is as hard as steel. It possesses good heat resistance. It is tough and having good corrosion resistance. Its melting point is 1452°C and specific gravity is 0.85. At normal temperature, nickel is paramagnetic. Nickel alloys are sometimes used for their high potential field strengths, some for their permeability and some for their high coercive force. When it contains small amount of carbon, it is quite malleable. It is somewhat less ductile than soft steel, but small amount of magnesium improves ductility considerably.

Applications

Nickel is used in kitchen utensils and appliances, and in laundry and dairy machinery. It is extensively useful for electroplating plating work for protecting surfaces of iron and brass from corrosion. It is also utilized as an important alloying element in some type of cast iron and steel. It is helpful for making stainless steel. Its alloys are discussed as under.

5.4.2 Nickel Alloys

The important nickel alloys are haste alloy, Monel metal, inconel, nomonic and ni-chrome.

5.4.2.1 Haste Alloy or high Temprature Alloy

Haste alloy or high temperature alloy is mainly a nickel base alloy. It contains

Ni = 45%,
Cr = 22%,
Mo = 9%,
Co = 1.5%,
W = 0.5%,
C = 0.15% and
Fe = Remaining

Properties

(*i*) It can be hot and easily cold worked, casted and welded.

(*ii*) It has high resistance corrosion especially to acids and salts except nitric acid (HNO_3).

(*iii*) It can be machined also.

(*iv*) This alloy is used where the resistance to corrosion is of consideration.

Applications

The high temperature alloys are those alloys which can withstand high temperatures about 1100°C. These alloys are used in components of nuclear plants, jet and rocket engines etc.

5.4.2.2 Monel Metal

Monel metal is an important alloy of nickel and copper. It contains 68% Ni, 30% Cu, 1% Fe and small amount of other constituents like iron, manganese, silicon and carbon.

Properties

Monel metal is superior to brass or bronze in resisting corrosion and in retaining its strength at high temperature. It is magnetic at ordinary temperatures. Its mechanical properties are improved by cold working. It can be cast, cold and hot worked, forged and welded. It resembles nickel in appearance and is strong, ductile and tough. It has good mechanical properties and can retain them even at elevated temperatures. It has high excellent corrosion resistance.

Applications

Monel metal is also used for pump fittings, condenser tubes, sea water exposed parts etc. It is widely used for making turbine blades, containers, parts for chemical plants, food handling machinery parts, marine parts, pump impellers, propellers, evaporators and heat exchangers in chemical works.

5.4.2.3 Inconel

Inconel contains

Ni = 80%
Cr = 14%
Fe = 6%

Properties

Inconel has high resistance to corrosion and oxidation at elevated temperatures. It can be readily cold-worked and hot-worked, but does not respond to heat treatment. It contains high mechanical properties coupled corrosion and heat resisting properties. It can be cast, forged, rolled and cold drawn. Its specific gravity is 8.55 and melting point is 1395°C. Its Brinell Hardness is about 160BHN. It can be soft soldered or can be welded by oxyacetylene welding.

Applications

Inconel is used for making springs, exhaust manifold of aircraft engines, machinery for food processing industries, especially milk and milk products. It is widely used for processing uranium and for sheathing for high temperature heating elements.

5.4.2.4 Nomonic alloy

The composition of nomonic alloy is given as under.

Cr = 15 to 18%
Co = 15 to 18%
Ti = l.2 to 4.0%
Al = l.5%
Ni = Remaining

Properties

(*i*) Nomonic is a special type of nickel alloy having good strength

(*ii*) It can be easily heat treated to attain excellent properties for very high temperature service.

Applications

Nomonic is widely used for making gas turbine engines

5.4.2.5 Ni-Chrome

Ni-chrome contains

Ni = 60%
Cr = 15%
Fe = 20%

Properties

Ni-chrome is non-corrosive. It can easily withstand high temperatures without oxidation.

Applications

Ni-chrome is commonly used for making electrical resistance wire for electric furnaces and heating elements.

5.5 LEAD

Lead is a bluish grey metal with a high metallic lusture when freshly cut. It is a very durable and versatile material. The heavy metal obtained from the bottom of the furnace is further oxidized in Bessemer's converter to remove most of the impurities.

Properties

Lead has properties of high density and easy workability. It has very good resistance to corrosion and many acids have no chemical action on it. Its melting point is 327°C and specific gravity is 11.35. It is the softest and heaviest of all the common metals. It is very malleable and may be readily formed into foil. It can readily be scratched with fingernail when pure.

Applications

The lead pipes installed by the Romans in the public baths in Bath, England, nearly 2000 years ago are still in use. Lead is used in safety plug in boilers, fire door releases and fuses. It is also used in various alloys such as brass and bronze. It finds extensive applications as sheaths for electric cables, both overhead and underground. Its sheets are used for making roofs, gutters etc. It is employed for chemical laboratory and plant drains. In the soldering process, an alloy of lead and tin is most widely utilized as a solder material for joining metals in joining processes.

5.6 ZINC

Zinc is bluish grey in color and is obtained from common ores of zinc are zinc blende (ZnS), zincite (ZnO), calamine (ZnCO3). These ores are commonly available in Burma. The oxide is heated in an electric furnace where the zinc is liberated as vapor. The vapors are then cooled in condensers to get metallic zinc.

Properties

Zinc possesses specific gravity is 6.2 and low melting point of 480°C. Its tensile strength is 19 to 25 MPa. It becomes brittle at 200°C and can be powdered at this temperature. It possesses high resistance to corrosion. It can be readily worked and rolled into thin sheets or drawn into wires by heating it to 100-150°C.

Applications

With regards to industrial applications, zinc is the fourth most utilized metal after iron, aluminium, and copper. Zinc is commonly used as a protective coating on iron and steel in the form of a galvanized or sprayed surface. It is used for generating electric cells and making brass and other alloys. The oxide of zinc is used as pigment in paints. Parts manufactured by zinc alloys include carburetors, fuel pumps, automobile parts, and so on.

5.7 TIN

Tin is recognized as brightly shining white metal. It does not corrode in wet and dry conditions. Therefore, it is commonly used as a protective coating material for iron and steel. The main source of tin is tinstone. Large deposits of tinstone occur in Tairy (Burma) and small quantities in Hazaribagh in Bihar of India

Manufacture

To obtain crude tin, the ores of tins are crushed, calcined, washed and then smelted in a furnace using anthracite coal and sand. The crude tin is then refined in a reverberatory

furnace to get commercially pure tin. Chemically pure tin is made by electrolytic deposition from commercial tin.

Properties

Tin is considered as a soft and ductile material. It possesses very good malleability. Its melting point is 232°C and specific gravity is 7.3. It is malleable and hence can be hammered into thin foils

Applications

Tin-base white metals are commonly used to make bearings that are subjected to high pressure and load. Tin is used as coating on other metals and alloys owing to its resistance to corrosion. It is employed in low melting point alloys as a substitute for Bismuth. It is generally preferred as moisture proof packing material. Because of its high malleability, it finds application in tin cans for storing food and food items.

5.7.1 Tin Base Alloy

Tin base alloy is also known as Babbitt metal which contains

Sn = 88%

Sb = 8%

Cu = 4%

Properties

Babbit metal possesses excellent antifriction properties and sufficient mechanical strength. It can be easily casted. It is expensive because of high tin content.

Applications

Because of the above properties, Babbit metal is the most common bearing metal used with cast iron boxes where the bearings are subjected to high pressure and load applications.

5.8. BEARING OR ANTIFRICTION ALLOYS

A bearing alloy or antifriction alloy commonly possesses good wearing quality, low co-efficient of friction, high thermal conductivity, good casting qualities, non-corrosive properties, ability to withstand high pressure and impact, low shrinkage after coating and less cost. Various Bearing Metals are:

5.8.1 Admiralty Gun Metal

The composition of admiralty gun metal generally contains

Cu = 88%

Sn = 10%

Pb = 2%

Properties

Admiralty gun metal is having tensile strength of the order of 270 MN/m^2. It possesses elongation of about 20% and Brinell Hardness of 65 BHN.

Applications

Admiralty gun metal is generally utilized where lubrication is needed and oiling is difficult.

5.8.2 Lead Bronze

Lead bronze generally contains

Cu = 80%
Sn = 10%
Pb = 10%

Properties

Lead bronze possesses tensile strength of 230 MN/m^2 , Brinell Hardness of 65 BHN and elongation of about 15%.

Applications

Lead bronze possesses has antifriction properties and hence is generally utilized where lubrication is doubtful.

5.8.3 Hard Bearing Bronze

Hard bearing bronze basically contains

Cu = 85%
Sn = 15%

Properties

Hard bearing bronze generally possesses tensile strength of 220 MN/m^2, 100 BHN and percentage elongation of 2%.

Applications

Hard bearing bronze is commonly used for high compressive loads such as locomotive slide valves etc.

5.9 CUTTING TOOL MATERIAL

Few material for cutting tools are generally used which are as follows.

(*i*) **High Speed Steel**

These have superior hot hardness and it can retain the hardness up to 900°C. In it tungsten produces martensite structure with other elements. It is three types

18-4-1 High Speed Steel.

It has 18% tungsten, 4% chromium, 1% vanadium and 0.7% carbon: This is used for machining or metal cutting speed above 50 m/min. But for higher cutting speed vanadium is increased.

Molybdenum high Speed Steel

It has 6% Molybdenum, 4% chromium and 2% vanadium.

Cobalt High Speed Steel

It is also known as super high speed steel. It has 1-12% cobalt, 20% tungsten, 4% chromium and 2% vanadium. It is very good for high cutting speed.

(*ii*) **Cemented Carbides**

The use of tungsten as an alloying elements gives steel the properly of retaining hardness at high temperature up to 900°C to 1000°C. Carbide is made by mixing tungsten metal powder with carbon and heating the mixture to the about 1600°C in the atmosphere of hydrogen until the two substance have under gone the chemical reaction to produce tungsten carbides. Cemented carbide is a powder metallurgical product. The powder of several carbide compounds are pressed and bonded together in a matrix to from a cemented material. Today, the following three groups of cemented carbides are extensively applied for cutting elements of tools.

(*a*) WC + Co + (WC-TiC-TaC-NiC) for use in the machining of steels.

(*b*) WC + Co for use in the machining of cast irons and non ferrous metals.

(*c*) TiC + Ni + Mo for use in the machining of high temperature high strength metals.

Cemented carbides have a very high hardness (second only to diamond) and high wear resistance to abrasion. They do not loose their cutting properties i.e., hardness over a wide range of temperature up to 900-1000°C. Therefore tools tipped with cemented carbides are capable of efficiently machining the hardest metals, including hardened steels at high cutting speeds. Such tools can operate at cutting speeds from 16 to 25 folds those permitted for tools made of carbon tool steels. One drawback of cemented carbides is their brittleness. Very high stiffness (Young's modulus is about three times that of steel) of the cemented carbides requires that they are well supported on a shank of sufficient thickness, for even a small amount of bonding deformation in a material of this stiffness may induce very high tensile stresses. Cemented carbides are weak in tension than in compression. They have a strong tendency to form pressure welds at low cutting speeds. In view of this they should be operated at speeds considerably in excess of those used with high speed steel tools. This caused for machine tools of increased power. Carbides that obtain high cobalt percentage are tougher and stronger than that contain low cobalt. Hence they are used for rough cutting, interrupted cuts and for milling. The low cobalt variety is used for finished operations such as turning with a smooth chip cross-section and a continuous cut. It is recommended to keep the braze metal as thin as possible.

(*iii*) **Ceramics Tool**

The latest development in the metal cutting tools uses Aluminium oxide, generally referred as ceramics. These tools are made by compacting Al_2O_3 powder in a mould at about 280 kg/cm^2 or more. The part is then sintered at 2200°C. This method is also known cold pressing ceramic tool. Hot pressed ceramic tool materials are expensive owing to their higher mould costs. These are made in form of tips that are clamped to metal shanks. These tools have very low heat conductivity and possess extremely high compressive strength. However they are quite brittle. The have low bending strength. They can with stand temperatures up to 1200°C and can be used at cutting speeds 10 times that of high speed cutting tools and 4 times that of cemented carbides. They are chiefly used for single point cutting tools for semi-finish and turning of cast iron, plastics and other work. Heat conductivity of ceramics is very low and hence these tools are generally used without a coolant.

(*iv*) **Carbides tool**

It may be produced from carbides of tungsten, titanium and tantanum with same percentage, of cobalt. The product is obtained by a special technique known as powder metallurgy. Usually it contains 82% tungsten, 8% cobalt and l0% titanium and the product is obtained by a special technique known as power metallurgy. Cobalt acts as a binder and others are very hard substance. This tool contains high degree of hardness and resistance. It is able to retain hardness at elevated temperatures up to l000°C. It can be operated at speeds 5 to 6 times or (more) higher than those with high speed steel.

(*v*) **Diamond**

It is a noble material which is so costly that its application becomes limited. It is a hardest material. It can be used for cutting at a speed 50 times greater than H.S.S. tools. It can retain its hardness even at a temperature of 1650. It has low coefficient of friction and high heat conductivity. Diamond tools are used to produce good surface finish.

5.10 COMPOSTION AND APPLICATIONS OF FEW TYPICAL MATERIALS

The composition and applications of few typical materials is given in Table 5.1.

Table 5.1 Composition and Applications of Few Typical Materials

S. No	Alloy	Composition	Uses
1	Duralmin,	95% Aluminium + 4% Copper+ 0.5% Manganese + 0.5% Magnesium	Light structures, extruded sections and sheet
2	Gun metal	90% copper + 10% zinc	Small valves, fittings for water services
3	Monel	67% Ni + 28% Copper + remaining carbon, iron and Manganese	Valve parts for superheated steam turbine blades
4	Phosphor bronze	90% Copper + 9.7% Tin + 0.3% Phosphorus	Bearings, worm wheels, rods sheets
5	High carbon steel	0.8% to 1.5% Carbon + remaining iron	Files, dies for wire drawing, clutch disc
6	Spheroidal CI	3.2%-4.5% carbon 1-4% Si 0.1-8% Mn 0.1% P 0-3.5% Ni 0.05-0.1% Mn	For high wear resistance
7	Wrought iron	99% Pig Iron + 0.12% Carbon + 0.25% Phosphorus + 0.05 % Sulphur	Chains, crane hooks, railway couplings

5.11 CERAMICS MATERIALS

Ceramic materials are non-metallic solids made of inorganic compounds such as oxides, nitrides, borides and carbides. Theses materials are fabricated by first shaping the powder with or without the application of pressure into a compact form and after that it is subjected to high temperature. Ceramics possesses electrical, magnetic, chemical and thermal properties which are exceptionally good.

Examples: MgO, CdS, SiC, Al_2O_3, glass, cement, garnets, ferrites, concrete etc.

Applications

Ceramic materials are utilized for making electronic control devices, computers, structures, components of nuclear engineering and aerospace field.

5.12 COMPOSITES

Composites are mixture of materials such as metal and alloys and ceramics, metals and organic polymers, ceramics and organic polymers.

Examples: Vinyl coated steels, steel reinforced concrete, fiber reinforced plastics, carbon reinforced rubber etc.

Applications

These materials are used for making sports items, structures, and electrical devices.

5.13 SEMICONDUCTORS

Semiconductors are solid materials, either non-metallic elements or compounds which allow electrons to pass through them. These materials occupy intermediate position between conductors and insulators. Semiconductors usually have high resistivity, negative temperature coefficient of resistance and are generally hard and brittle.

Examples: Germanium (Ge), Arsenic (As), Silicon (Si), Boron (B), Sulphur (S), Selenium (Se).

Applications

Semiconductors are utilized in making devices used in areas of telecommunication and radio communication, electronics and power engineering, photocells, rectifiers etc.

5.14 ORGANIC POLYMERS

Polymers consist of carbon chemically combined with usually with hydrogen, oxygen or other non- metallic substances. They are formed by polymerization reaction in which simple molecules are chemically combined into long chain molecules.

Examples: Nylon, Teflon, Polyethylene, PVC, Terylene, Cotton etc.

Applications

Polymers are used in making packings, pipes, covers and insulating materials etc.

5.15 PLASTICS

Plastics are commonly known as synthetic resins or polymers. In Greek terminology, the term polymer comprises ‘poly’ means ‘many’ and ‘mers’ means ‘parts’. Thus, the term, polymer represents a substance built up of several repeating units, each unit being known as a monomer. Thousands of such units or monomers join together in a polymerization reaction to form a ‘polymer’. Some natural polymers like starch, resins, shellac, cellulose, proteins, etc are vary common in today’s use. Synthetic polymers possess a number of large applications in engineering work. Therefore plastic materials are fairly hard and rigid and can be readily molded into different shapes by heating or pressure or both. Various useful articles can be produced from them rapidly, accurately and with very good surface quality. They can be easily

produced in different colors or as transparent. They are recognized by their extreme lightness, good corrosion resistance and high dielectric strength. Plastics are synthetic resins characterized as a group by plastic deformation under stress. These materials generally are organic high polymers (i.e. consisting of large chain like molecules containing carbon) which are formed in a plastic state either during or after their transition from a low molecular weight chemical to a high molecular weight solid material. These materials are very attractive organic engineering materials and find extensive applications in industrial and commercial work such as electrical appliances, automotive parts, communication products bodies (Telephone, Radio, TV), and those making household goods. They possess a combination of properties which make them preferable to other materials existing in universe.

Properties of plastics

The properties of plastics are given as under.

1. Plastics are light in weight and at the same time they possess good toughness strength and rigidity.
2. They are less brittle than glass, yet they can be made equally transparent and smooth.
3. Their high dielectric strength makes them suitable for electric insulation.
4. They resist corrosion and the action of chemicals.
5. The ease with which they can be mass-produced contributes greatly to their popularity as wrappers and bags.
6. They possess the property of low moisture absorption.
7. They can be easily molded to desired shapes.
8. They can easily be made colored.
9. They are bad conductance of heat.
10. They are hard, rigid and heat resistance.
11. They possesses good deformability, good resiatance against weather conditions, good colorability, good damping characteristics and good resistance to peeling.

Plastics are broadly classified into thermo plastics and thermo-setting plastics.

5.15.1 Thermo Plastics

Those plastics which can be easily softened again and again by heating are called thermoplastic. They can be reprocessed safely. They retain their plasticity at high temperature, i.e. they preserve an ability to be repeatedly formed by heat and pressure. Therefore, they can be heated and reshaped by pressing many times. On cooling they become hard. They are some times also called as cold-setting plastics. They can be very easily shaped into tubes, sheets, films, and many other shapes as per the need.

Types of Thermo Plastics

(A) Amorphous

1 Polystyrene

2 Acrylonitrite-butadiene-styrene

3 Mrthacrylate

4 P.V.C (Polyvinyl chloride)
5 Polychloroacetal
6 Auorinated polymers,
7 Polycarbonate etc.

(B) Crystalline

1 Polyethylene
2 Polyamides
3 Polyacetal
4 Polypropylene

The reason for the re-softening of thermoplastic resins with heat is that they are composed of linear or long chain molecules. Application of heat weakens the intermolecular bonds by increasing thermal agitation of the molecules, and the material softens and thus plastic can be easily molded and remolded without damage

5.15.2 Thermo-Setting Plastics

Those plastics which are hardened by heat, effecting a non-reversible chemical change, are called thermo-setting. Alternatively these plastics materials acquire a permanent shape when heated and pressed and thus cannot be easily softened by reheating. They are commonly known as heat-setting or thermosets.

Thermosetting resins

(*i*) Phenol-formaldehyde resins
(*ii*) Urea-formaldehyde resins
(*iii*) Melamine-formaldehyde resins
(*iv*) Polyester resins
(*v*) Epoxy resins
(*vi*) Silicone resins

Other thermosetting compounds are phenol furfural, polysters, alkyds, and polyurethanes. The most common thermosetting compound is phenol formaldehyde which is discussed as under.

Phenol formaldehyde

Phenol formaldehyde is called as bakelite due to the name of its inventor Bakelite. It is the most commonly and widely used plastic. It is made by the reaction of phenol with formaldehyde. It has high strength, hardness, stability, rigidity and can be easily casted or laminated. It is highly resistant to heat, electricity and water. It is made in dark color shades. Its general uses are in making articles such as stereo cabinets, radio cabinets, plugs, knobs, dials, bottle cap, pulleys, wheels, telephones, switches and handles.

Thermosetting resins, when subjected (once only) to the heat and pressure required for forming, change into a hard and rigid substance. Once done so, they cannot be softened again by the application of heat. The reason for the above phenomenon is that the thermosetting plastics consist of linear, relatively low molecular weight thermoplastic polymer chains with cross-links which bond the chains together with primary valence bonds. Such three-dimensional

polymers, once cross-linked, will not soften when heated (but may decompose disintegrate at higher temperatures) because this process is an irreversible chemical reaction and the entire structure becomes essentially a single molecule. In contrast the thermoplastic resins can be re-softened and remolded by application of heat and pressure. They retain their plasticity at high temperature, i.e. they preserve an ability to be repeatedly formed by heat and pressure.

5.15.3 Comparison Between Thermo Plastic and Thermosetting Plastic

Thermoplastic are those which are obtained from the substituted derivatives of ethylene which can be made to polymerize under the influence of heat and catalyst. These materials are softened by heat and affected by certain solvent. A notable feature of these resins is the ability of their scrap or rejects to be reworked along with the new material. Cellulose nitrate (celluloid) and polythene are the example of these materials. Where as thermosetting are those which are formed into shape under heat and pressure and results in a permanently hard product. The heat first softens the material, but as additional heat and pressure is applied, it becomes hard phenol formaldehyde (bakelite). Phenol furfural (Durite) is the example of thermosetting plastics. The comparison between thermo plastic and thermosetting plastic is given in Table 5.2.

Table 5.2 Comparison between Thermo Plastic and Thermosetting Plastic

S.No	Thermo Plastic	Thermosetting Plastic
1	They can be repeatedly softened by heat and hardened by cooling.	Once hardened and set, they do not soften with the application of heat.
2	They are comparatively softer and less strong.	They are more stronger and harder than thermoplastic resins
3	Objects made by thermoplastic resins can not be used at comparatively higher temperature as they will tend to soften under heat.	Objects made by thermosetting resins can be used at comparatively higher temperature without damage
4	They are usually supplied as granular material	They are usually supplied in monomeric or partially polymerized material form in which they are either liquids or partially thermoplastic solids.
5	Applications. Toys, combs, toilet goods, photographic films, insulating tapes, hoses, electric insulation, etc.	Applications. Telephone receivers, electric plugs, radio and T.V. cabinets, camera bodies, automobile parts, tapes, hoses, circuit breaker switch panels, etc.

5.15.4 Fabricating of Plastics

(*a*) Themo-plastics can be formed by

(*i*) Injection molding.

(*ii*) Extrusion.

(*iii*) Blow molding.

(*iv*) Calendaring

(*v*) Thermo-forming.

(*vi*) Casting.

(*b*) Thermosetting plastics can be formed by

(*i*) Compression or transfer molding.

(ii) Casting

Thermoplastics can be joined with the help of

(*i*) Solvent cements.

(*ii*) Adhesive bonding

(*iii*) Welding

(*iv*) Mechanical fasteners

Thermosetting plastics can be joined with the help of

(*i*) Adhesive bonding

(*ii*) Mechanical fasteners.

5.15.5 Additions in Polymer

To make polymer more for further processing of products, plastics, and some other material are added to the polymers before or during polymerization. These materials are

Catalysts

They are also known accelerator or hardener. They act as catalysts to accelerate the chemical reactions during polymerization of plastics.

Fillers

Fillers are added to synthetic resins for increasing strength, stiffness and thermal resistance of the plastics. These are clay, talc, alumina, carbon black, calcium carbonate, wood flour, mica, quartz, asbestos, glass fibres etc.

Modifiers

Modifiers are added to plastics for improving mechanical properties

Plasticizers

Plasticizers are fluids of high molecular weight. They are added for softening the resins at forming temperature and to improve their toughness at the finished stage and to impart flexibility to their finished products.

Stabilizers

The additions of stabilizers to plastics help in preventing deterioration due to the action of heat and light.

Initiators

Initiators help in starting the reaction i.e. polymerization.

Dyes and pigments

Dyes and pigments are the coloring agents, added to impart different colors and shades to plastic materials.

5.16 MATERIALS FOR NUCLEAR ENGINEERING PURPOSES

The various metals for producing nuclear energy are used as main materials namely moderators, reflectors, fuel elements, fuel canning materials, control elements, and pressure

vessel materials. Uranium, thorium, plutonium, zirconium, beryllium, niobium and their alloys are primarily used for nuclear engineering applications.

5.16.1 Uranium

Most important metal found in nature and used for nuclear energy is uranium. It is used as a nuclear fuel and is radioactive, easily oxidized mat and exists in three allotropic forms. It has a poor resistance to corrosion and needs to be protected for use as fuel elements by roll cladding a thin aluminium or zirconium jacket. Therefore it is strengthened by a thin film of aluminium or zirconium through a rolling process known as cladding. This metal in the pure condition is weak and is susceptible to severe irradiation damage and growth in the reactor environments. Addition of some alloying elements such as chromium, molybdenum, plutonium and zirconium are added to make great use of this material for generating nuclear power. Uranium compounds have been found to give better service. Uranium oxide is re highly refractory, shows no phase change in an inert atmosphere, possesses a good strength and a high corrosion resistance. But it has a low thermal shock resistance, poor thermal conductivity and a high coefficient of in expansion. The melting point of uranium is 1850°C.

5.16.2 Thorium

Thorium is another possible fuel and is also a radioactive metal like uranium. It is a nuclear fuel and is free from phase changes below 1480°C. It can be converted into uranium by beta decay. It can be converted into uranium by beta decay. In its pure form it is weak and soft, but its mechanical properties are improved by adding small amount of other elements e.g., only 0.2% of carbon addition raises its tensile strength from. Its mechanical properties change drastically by small addition of impurities. Small additions of titanium, zirconium, and niobium decrease the strength and hardness of the metal. Uranium addition increases the strength of thorium. Thorium like uranium is an emitter of alpha rays and releases considerable quantity of the radioactive products during processing, but this being a cubic metal is less susceptible to irradiation damage. The melting point of thorium is 1845°C.

5.16.3 Plutonium

Plutonium is not a natural element but synthetic. It is produced through the absorption of neutrons by uranium 238 and subsequent beta decays. It is a concentrated type of fuel used in a fast reactor without a moderator. It is identified as highly toxic and chemically very reactive material. It has a poor resistance to corrosion. This material can be easily oxidized. It is frequently used for production of atomic weapons and it possesses tremendous applications in breeder reactors.

5.16.4 Zirconium

The natural form of zirconium contains 0.5 to 2% halfnium which is a strong absorber of neutrons and must therefore be removed. It possesses excellent corrosion resistance against most of the acids and having good strength, good weldability and fatigue resistance. It has a poor resistance to CO_2 at elevated temperatures and that can be further improved by adding 0.5% Cu and 0.5% Mo. It is specifically used in gas cooled reactors and cladding of fuel elements.

5.16.5. Beryllium

Beryllium is specially used as a moderator, reflector and neutron source in nuclear reactors. It is a coarse grained light and brittle metal which possesses highly developed texture. During

melting, vacuum or inert gas is necessary because it is very reactive and forms compounds with the furnace atmosphere and refractory materials. In order to fabricate components from beryllium, powder metallurgy techniques are used.

5.16.6. Niobium

Niobium possesses good corrosion resistance, strength and ductility. It has a high melting point of 2470°C. Its oxidation resistance above 400°C is indifferent, but can be greatly improved by alloying elements. It is added to many base metals to produce heat resisting alloys but this material is quite expensive.

5.17 MATERIAL SELECTION PROCEDURE FOR COMPONENTS

For selection a material for a particular application, one has to take into consideration various physical and mechanical properties of the material. Selection of material for a manufacturing process is an important decision. In many instances, the selection of a specific material can even dictate the manufacturing process to be used. The selection of material also has an influence on the final cost of the product. It is important to note that the material cost accounts to approximately 50% of the manufacturing cost. Hence, selection of manufacturing process for a material must be made with the due care. The stepwise approach for material selection is as follows:

1 Initially material requirement is identified by keeping in view overall objectives of the part for which the selection of material is made. These objectives can be referred with reference to cost, durability, life, etc.

2 The material requirements are identified through a number of materials. For example, low specific weight requirement is met by aluminium and also by nylon. Make a list of all such materials that meet all or most of the, requirements.

3 In case when more than one material appears to be suitable, the final choice should be determined by considering influencing factors and restrictions like availability of raw material, cost, inhibitions of aesthetics, and so on. For example, when we want to select a material for manufacturing coins, the requirements are: the material should possess good ductility, hardness, corrosion resistance, high plasticity, and should be light in weight. The list of materials that satisfy these requirements is large including gold, silver, copper, and their alloys. Final selection may be made taking into consideration cost and availability. As another example, one uses stainless steel for manufacturing shaving razor blades because the material selected should have good malleability (ability to be hammered into thin sheets), corrosion resistance, more abrasive resistance, and economical. The edge may be alloyed to make it hard and retain sharpness.

The material selection procedure for the following products is given as under.

Rock crusher jaw

The function of crusher jaws is to crush. The crusher jaws should be hard, shock absorbing and require good compressive strength. For such properties we choose cast-iron because it has good castability, fluidity and good damping capacity. Its castings are made by dry sand casting process.

Binocular Body

It is made by plastic materials containing cellulose acetate (Thermo plastics), polystyrene (thermoplastics) phenol formaldehyde (thermo setting plastics) because these materials have high mechanical strength, impact resistance, transparency, colorability, fabricating quality, versatility, molding ability, high dielectric strength and high refractive index.

Diesel Engine Piston

As the function of piston to reciprocate in the cylinder, it will require good wear and corrosion resistance and ability to with stand at high temperature. Therefore material like cast iron, bronze and aluminium alloy etc are preferred because of the requirements of lightness with sufficient strength, refractoriness stress relieving, hardening, and tempering,

Lifting hook of crane

The purpose hook in crane is to lift load and it will require bearing sudden and excessive heavy shock-loads without permanent injury. For such purposes wrought iron will prove better and it is not heat-treated.

Bed of high precision lathe

Bed of high precision lathe needs high compressive strength, better shock absorbing capacity, good damping capacity, corrosion resistance and good wear resistance, hardness and reduced effect of residual stresses for better functional requirements. Grey cast iron because its good lubricating properties due to presence of graphite will be suitable to meet the functional requirements. However for increasing its usefulness alloying elements such as Ni, Cr and Mo etc can also be alloyed in grey cast iron.

5.18 QUESTIONS

1. How do you classify non-ferrous metals?
2. Discuss the properties and uses of the following non-ferrous metals:
   (*i*) Copper (*ii*) Zinc (*iii*) Aluminium (*iv*) Magnesium
   (*v*) Lead (*vi*) Tin (*vii*) Nickel. (*viii*) Plutonium
3. What is brass? Describe the composition, properties and uses of important types of brasses?
4. What is bronze? Describe the composition, properties and uses of different types of bronzes?
5. Explain the various types of aluminium alloys giving their composition, properties and uses?
6. Discuss the various types of nickel alloys?
7. Which are the main metals used in nuclear energy? Describe them in brief.
8. How will you select the suitable engineering materials for a particular application?

6
CHAPTER

MELTING FURNACES

6.1 INTRODUCTION

Before pouring into the mold, the metal to be casted has to be in the molten or liquid state. Furnace is used for carrying out not only the basic ore refining process but mainly utilized to melt the metal also. A blast furnace performs basic melting (of iron ore) operation to get pig iron, cupola furnace is used for getting cast iron and an electric arc furnace is used for re-melting steel. Different furnaces are employed for melting and re-melting ferrous and non-ferrous materials. The following are the factors which are responsible for the selection of furnace.

(*i*) Considerations of initial cost and cost of its operation.
(*ii*) Relative average cost of repair and maintenance.
(*iii*) Availability and relative cost of various fuels in the particular locality.
(*iv*) Melting efficiency, in particular speed of melting.
(*v*) Composition and melting temperature of the metal.
(*vi*) Degree of quality control required in respect of metal purification of refining,
(*vii*) Cleanliness and noise level in operation.
(*viii*) Personnel choice or sales influence.

Heat in a melting furnace is created by combustion of fuel, electric arc, electric resistance, etc. A furnace contains a high temperature zone or region surrounded by a refractory wall structure which withstands high temperatures and being insulating minimizes heat losses to the surroundings. For refining and melting the ferrous and non ferrous materials, various furnaces are used.

6.2 FURNACES FOR MELTING DIFFERENT MATERIALS

1. Grey Cast Iron

(*a*) Cupola
(*b*) Air furnace (or Reverberatory Furnace)
(*c*) Rotary furnace
(*d*) Electric arc furnace

2. Steel

(*a*) Electric furnaces

(*b*) Open hearth furnace

3. Non-ferrous Metals

(*a*) Reverberatory furnaces (fuel fired) (Al, Cu)

  (*i*) Stationary

  (*ii*) Tilting

(*b*) Rotary furnaces

  (*i*) Fuel fired

  (*ii*) Electrically heated

(*c*) Induction furnaces (Cu, Al)

  (*i*) Low frequency

  (*ii*) High frequency.

(*d*) Electric Arc furnaces (Cu)

(*e*) Crucible furnaces (AI, Cu)

  (*i*) Pit type

  (*ii*) Tilting type

  (*iii*) Non-tilting or bale-out type

  (*iv*) Electric resistance type (Cu)

(*f*) Pot furnaces (fuel fired) (Mg and AI)

  (*i*) Stationary

  (*ii*) Tilting

Some of the commonly used furnaces in foundries are discussed as under.

6.3 BLAST FURNACE

After mining, various kinds of iron ores are brought to the blast furnace which is the starting process for refining iron ores or mined ores and for the poduction of pig iron. Blast furnace was invented in 14th century. A typical blast furnace along with its various parts is shown in Fig. 6.1. It is large steel shell about 9 mt. in diameter which is lined with heat resistant bricks. It is set on the top of brick foundation. There are four major parts of blast furnace from bottom to top hearth, bosh, stack and top. The hearth acts as a storage region for molten metal and molten slag. The charge of blast furnace possesses successive layers of iron ore, scrap, coke, and limestone and some steel scrap which is fed from the top of the furnace. Iron ore exists as an aggregate of iron-bearing minerals. These mineral aggregates are oxides of iron called hematite, limonite, and magnetite. They all contribute to the smelting process. Hematite is a red ore and contains about 70% iron. Limonite is a hydrated oxide and contains about 60% iron. Magnetite is a magnetic oxide and contains about 72% iron. It takes about 1.6 tons of iron ore, 0.65 ton of coke, 0.2 ton of lime-stone and about 0.05 ton of scrap iron and steel to produce 1 ton of pig iron. For burning this charge, about 4 tons of air is required. The impurities or other minerals are present in the ore. These impurities may be silicon,

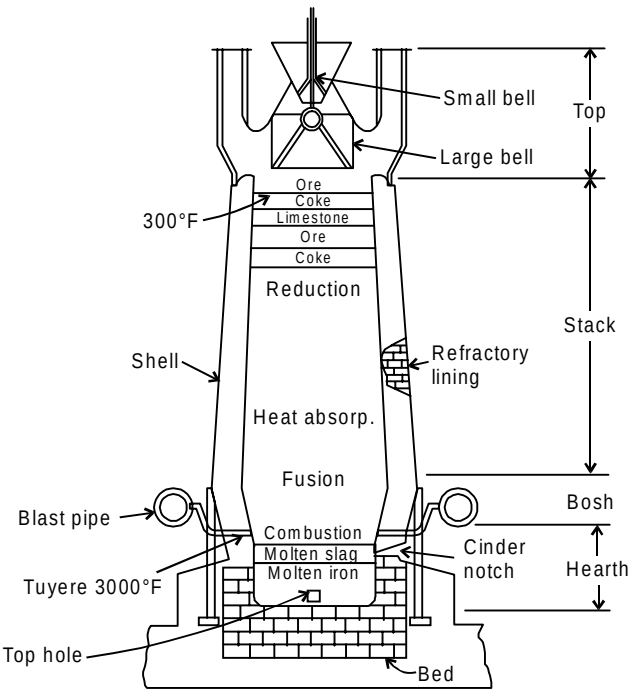


Fig. 6.1 Typical blast furnace

sulfur, phosphorus, manganese, calcium, titanium, aluminum, and magnesium. The amounts of silicon, phosphorus, and sulfur present will determine the purification process used in the manufacture of the steel. The output from the furnace in form of pig iron is collected in large ladles from the tap hole existing at lower portion of furnace. As the coke burns, aided by the air forced into the furnace, the ore melts and collects in the hearth. As the melting process proceeds, the entire mass settles and thus makes room for the addition of charges at the top. While the melting is going on, the limestone forms a slag with the impurities. The second component which makes up the charge is the coke which is made from coal. Coke must be dust proof, not too combustible, and strong, since it must support the charge. It supplies the heat which reduces the ore and melts the iron. The iron picks up carbon from the coke and impurities from the ore. The amount of carbon picked up by the iron is more than is needed in the production of steel. The carbon becomes part of the pig iron used in the making of steel. The control of this carbon during the subsequent processes determines the properties of the steel. The manufacture of coke from bituminous coal is a distillation process. The impurities are driven off leaving coke.

The pig iron is then processed for purification work for production of various kinds of iron and steel in form of ingots (large sections) using different furnaces. Fig 6.2 shows a flow chart for production of different kinds of iron and steel. The steel ingots can be further processed in rolling mill or blooming mill to produce different structural shapes and sections of steel. Fig 6.3 represents the entire process for production of market form of steel supply of different shapes or sections.

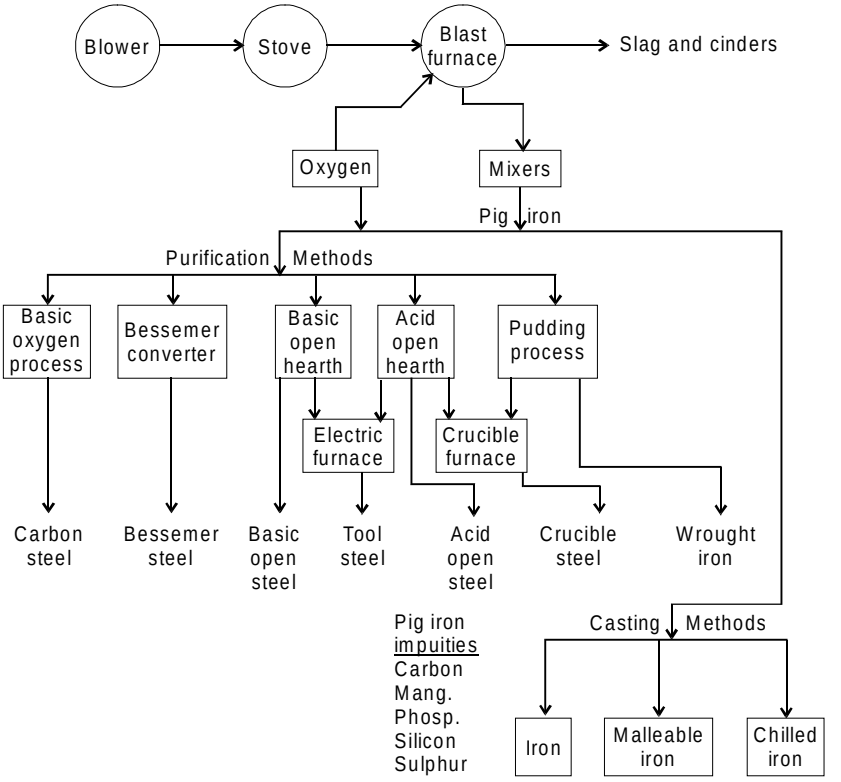
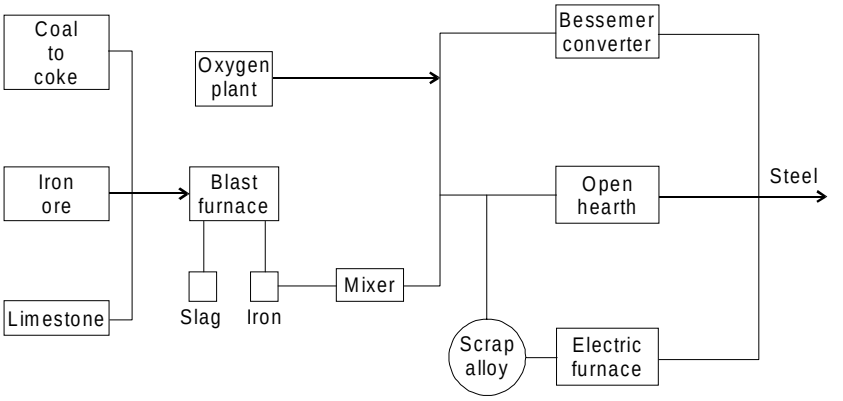


Fig. 6.2 Flow chart for converting pig iron into useful iron and steel

6.4 CUPOLA FURNACE

Cupola furnace is employed for melting scrap metal or pig iron for production of various cast irons. It is also used for production of nodular and malleable cast iron. It is available in good varying sizes. Fig. 6.4 shows the various parts and zones of cupola furnace. The main considerations in selection of cupolas are melting capacity, diameter of shell without lining or with lining, spark arrester.



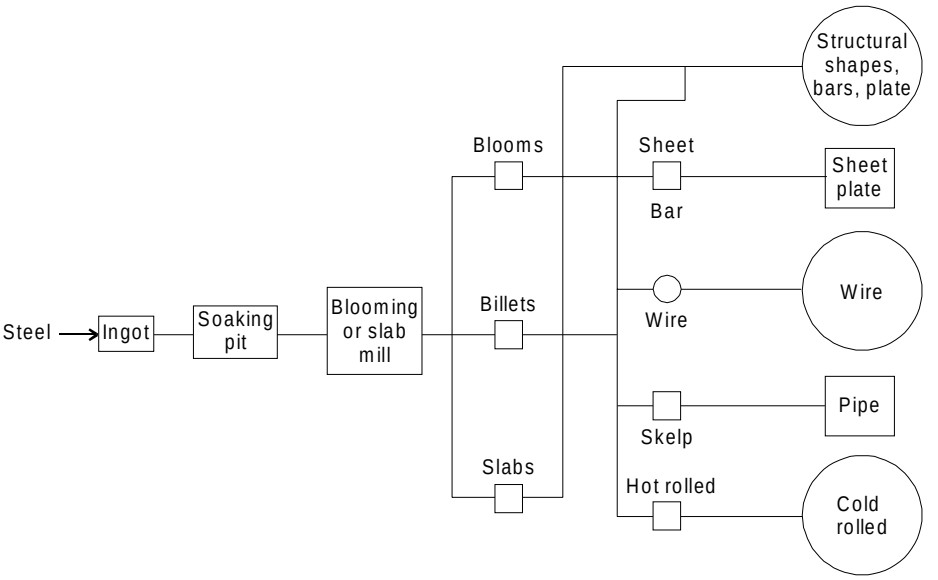


Fig. 6.3 Production process of market form of steel supply of different shapes or sections

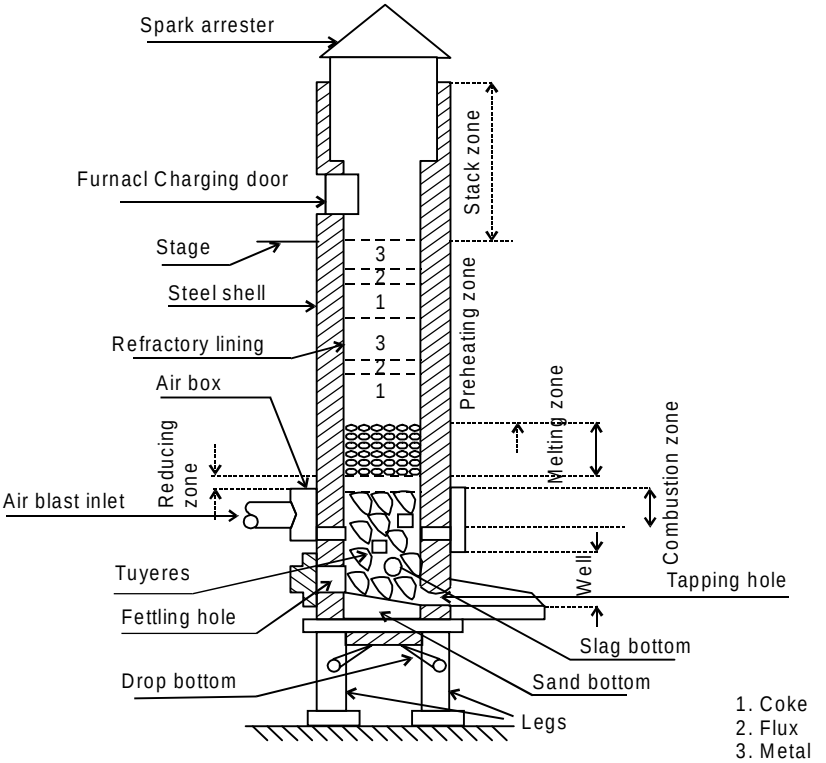


Fig. 6.4 Cupola furnace

6.4.1 Various Zones of Cupola Furnace

Various numbers of chemical reactions take place in different zones of cupola. The construction and different zones of cupola are discussed as under.

1. Well

The space between the bottom of the tuyeres and the sand bed inside the cylindrical shell of the cupola is called as well of the cupola. As the melting occurs, the molten metal is get collected in this portion before tapping out.

2. Combustion zone

The combustion zone of Cupola is also called as oxidizing zone. It is located between the upper of the tuyeres and a theoretical level above it. The total height of this zone is normally from 15 cm. to 30 cm. The combustion actually takes place in this zone by consuming the free oxygen completely from the air blast and generating tremendous heat. The heat generated in this zone is sufficient enough to meet the requirements of other zones of cupola. The heat is further evolved also due to oxidation of silicon and manganese. A temperature of about 1540°C to 1870°C is achieved in this zone. Few exothermic reactions takes place in this zone these are represented as :

$$C + O_2 \longrightarrow CO_2 + Heat$$
$$Si + O_2 \longrightarrow SiO_2 + Heat$$
$$2Mn + O_2 \longrightarrow 2MnO + Heat$$

3. Reducing zone

Reducing zone of Cupola is also known as the protective zone which is located between the upper level of the combustion zone and the upper level of the coke bed. In this zone, CO_2 is changed to CO through an endothermic reaction, as a result of which the temperature falls from combustion zone temperature to about 1200°C at the top of this zone. The important chemical reaction takes place in this zone which is given as under.

$$CO_2 + C \text{ (coke)} \longrightarrow 2CO + Heat$$

Nitrogen does not participate in the chemical reaction occurring in his zone as it is also the other main constituent of the upward moving hot gases. Because of the reducing atmosphere in this zone, the charge is protected against oxidation.

4. Melting zone

The lower layer of metal charge above the lower layer of coke bed is termed as melting zone of Cupola. The metal charge starts melting in this zone and trickles down through coke bed and gets collected in the well. Sufficient carbon content picked by the molten metal in this zone is represented by the chemical reaction given as under.

$$3Fe + 2CO \longrightarrow Fe3C + CO_2$$

5. Preheating zone

Preheating zone starts from the upper end of the melting zone and continues up to the bottom level of the charging door. This zone contains a number of alternate layers of coke bed, flux and metal charge. The main objective of this zone is to preheat the charges from room temperature to about 1090°C before entering the metal charge to the melting zone. The preheating takes place in this zone due to the upward movement of hot gases. During the preheating process, the metal charge in solid form picks up some sulphur content in this zone.

6. Stack

The empty portion of cupola above the preheating zone is called as stack. It provides the passage to hot gases to go to atmosphere from the cupola furnace.

6.4.2 Charging of Cupola Furnace

Before the blower is started, the furnace is uniformly pre-heated and the metal and coke charges, lying in alternate layers, are sufficiently heated up. The cover plates are positioned suitably and the blower is started. The molten metal starts trickling down and collecting in the well. The height of coke charge in the cupola in each layer varies generally from 10 to 15 cms. The requirement of flux to the metal charge depends upon the quality of the charged metal and scarp, the composition of the coke and the amount of ash content present in the coke. Generally about 40 kg to 50 kg of limestone, in form of flux, per metric ton of the metal is used. The amount of this flux to be charged should be properly determined. The excess amount of flux affects the acid lining of cupola. Lesser amount of the flux than required will result in the loss of molten metal. First charge received of the molten metal is either allowed to drain out or used for rough castings. For having desired composition of the casting, it is essential to control the proportions of its various constituents at the stage of raw material requirement for melting. It is also necessary due to number of losses and gains of different constituents take place inside the cupola during the process of melting. These losses and gains in composition are identified for compensating purposes. The losses or gains of different constituents during melting as identified are given as under:

1. Iron – Loss of about 4%
2. Carbon – Gain of about 0.1 to 0.15%.
3. Silicon – Loss of about 10%
4. Manganese – Loss of about 15 to 20%.
5. Phosphorus – Practically no change.
6. Sulphur – Gain of about 0.03 to 0.05%.

6.4.3 Working of Cupola Furnace

Initially the furnace prop is opened to drop the existing earlier charge residue. The furnace is then repaired using rich refractory lining. After setting the prop in position, the fire is ignited using firewood and then small amount of coke is used to pick fire. The little oxygen is then supplied for combustion**.** Lime, coke, and metal in balanced proportions are charged through the charging door upon the coke bed and at proper time on starting the blower. Air is forced from wind box through tuyers into furnace. The forced air rise upward rough the stack furnaces for combustion of coke. Besides being fuel, the coke supports the charge until melting occurs. On increase of temperature, the lime stone melts and forms a flux which protects the metal against from excessive oxidation. Lime also fuses and agglomerates the coke ash. The melting occurs and proceeds and molten metal is collected at the bottom. Molten metal may be tapped at intervals before each skimming, or the tap-hole may be left open with metal flowing constantly. In most cupolas slag is drained from the slag hole at the back of furnace. When metal is melted completely the bottom bar is pulled sharply under the plates and bottom is dropped. All remaining slag, un-burned coke or molten metal drops from the furnace. When the melt charge has cooled on closing furnace, it is patched and made ready for the next heat.

Applications of Cupola

Cupola is most widely used for melting practices for production of grey cast iron, nodular cast iron, malleable cast iron and alloy cast iron. It can be used for melting some copper-base alloys, and in duplexing and triplexing operations for making of steel, malleable cast iron and ductile cast iron. Steel can be also prepared in cupola by employing duplexing and triplexing

operations. In duplexing melting operation two furnaces are used, and triplexing operations, three furnaces are employed

6.4.4 Jamming of Cupola Furnace

Jamming of cupola furnace is a very common problem for which sufficient care should be taken to prevent it. It occurs frequently due to the negligence of the furnace operator. The cupola furnace may be either jammed temporarily or permanently and the same are discussed as under.

6.4.5 Temporary Jamming of Cupola Furnace

Temporary jamming of cupola furnace means the temporary suspension of air supply in the tuyere zone due to choking of the tuyere mouths. This is caused mainly due to the low temperatures at the tuyere openings resulting in the solidification of iron and slag around these openings. The air passage is hence chocked and the supply of air is temporarily stopped. It results in incomplete combustion of the coke/fuel inside the furnace and hence leads to rapid reduction of the temperature in the furnace. Therefore this temporary jamming must be prevented by frequent poking of this solidified material by means of a poking bar through the tuyeres. The operator of cupola should always keep himself alert enough for not allowing such solidification for continue melting in furnace for a longer period.

6.4.6 Permanent Jamming of Cupola Furnace

Permanent jamming of cupola furnace means a complete cut-off of the air supply to the cupola due to the permanent choking of the air passage. This occurs on account of the overflow of the slag into the wind chamber. As the metal melts and starts collecting in the well of the furnace, its level rises gradually and the slag being lighter, always floats on the top surface of the molten metal. If, the molten metal is not tapped out in time due to the negligence of the operator, the level of molten metal in furnace will start rising in the well and a stage will come when this level approaches to the tuyere level. Any slightest delay further, in tapping by the cupola operator will cause the slag to flow through the tuyere openings into the wind belt. Since the slag comes in contact with the air at low temperature it quickly solidifies in the wind belt as well as in the tuyers and therefore chock the passages of air flow permanently in the furnace. Hence the cupola furnace reaches in such undesirable condition on account of the above occurrence. Therefore, to avoid such undesired situation, the operator of cupola furnace should always be vigilant enough to tap the molten metal out from well of the cupola furnace before the level of molten metal rises up to the tuyere level. Hence the cupola furnace may continue melting for longer period.

6.4.7 Thermal Efficiency of Cupola Furnace

Thermal efficiency of cupola furnace is the ratio of heat actually utilized in melting and superheating the metal to the heat evolved in it through various means. The total heat evolved involves the heat due burning of coke, heat evolved due to oxidation of iron, Si and Mn and heat supplied by the air blast. During melting it is observed that approximately 48-70 % of the evolved heat is going as waste.

6.4.8 Precautions for Safety of Cupola Furnace

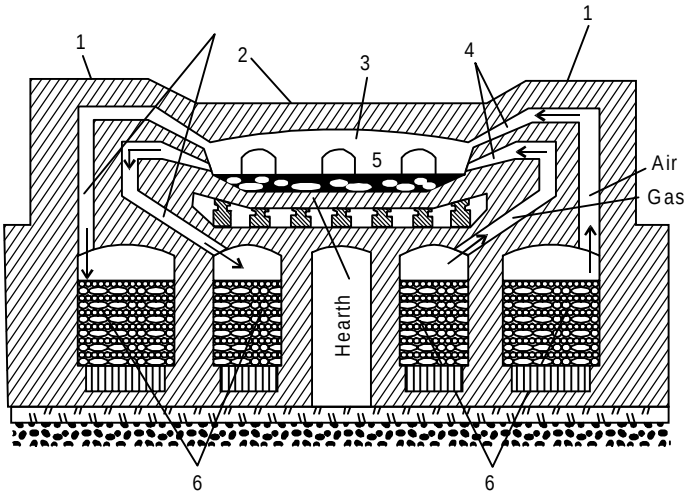
For operating the cupola successfully, the following safety precautions must always be kept into account.

1. For safety of Cupola, better quality refractory lining must be used for preparing or repairing furnace so that it can withstand high temperature as produced inside the furnace during melting, otherwise it will fuse and mix with molten metal to form slag.
2. The furnace operator during firing the furnace should always make an effort to place the metal charge in the centre. He must ensure that the coke charge is well distributed all around and towards the firebrick lining to ensure uniform and thorough melting of the metal.
3. As the air passes through the tuyeres, the temperature near the tuyere openings will therefore be comparatively lower and consequently the molten iron and slag will have a tendency to solidify near these openings and block them. This should be prevented by frequent poking and removal of these materials by means of a poking rod through the tuyeres.
4 Amount of air supply should be properly controlled. An excess amount of air will always result in waste of fuel and lowering of temperature inside and a lesser amount, than required, will cause incomplete combustion of fuel which is undesirable.
5. Tap hole must be properly closed by means of a well suitable plugging means. Clay mixed with an equal amount of coal dust forms a very suitable mixture for plugging up the tap hole.
6 In closing the tap-hole, precaution must be taken to press the plug downwards in the hole so that the splash of the molten metal, during plugging does not fall on the hands of the furnace operator.
7 Molten metal should always be tapped out well in time before its level rises too high in the well of the cupola furnace. Any delay of tapping molten metal, the slag floating on the surface of the molten metal, will start flowing into the wind belt through the tuyeres and air passage will be choked and it will result in severe problem of the jamming of cupola furnace.

6.5 OPEN HEARTH FURNACE

In open hearth furnace, pig iron, steel scrap etc. are melted to obtain steel. This furnace is widely used in American foundries for steel production. The hearth is surrounded by roof and walls of refractory bricks as shown in Fig. 6.5. The charge is fed through a charging door and is heated to 1650°C mainly by radiation of heat from the burning of gaseous fuels above it. This heat is obtained by the burning of sufficiently pre-heated air and gas. Such pre-heated air of gas is obtained by passing them though arc shaped hot regenerators at a lower level. This contains fire bricks which are arranged to extract heat from exhaust gases. In the furnace air and fuel are passed through a honeycomb of hot firebrick, called checkers. It preheats the air and fuel so that they are ready for combustion when they enter the hearth. The products of combustion at the same time pass through the checkers at the other end of the furnace. The hot gases heat the checkers. The process then reverses itself, and the newly heated checkers now are used to heat the air and the fuel. It is said as a regenerative process. The products of combustion after giving up their heat to the checkers pass up through the stack. On firing of coke, the charge is heated. Part of the heat necessary, results from radiation from the low hot roof of the chamber. The furnace is raised bricked in with the charging platform, at the rear, also raised so that the charge may be put into the furnace. The melt is tapped off the front into large ladles.

The chemical composition of the end product depends upon the lining, the charge, and the control impurities added during the melt after the melt has been tapped off into the ladle. The lining plays a major roll in the control of impurities. For magnesite lined furnace, the charge consists of pig iron, limestone, and scrap iron. The limestone forms a slag. This slag and the oxygen in the air combine to remove impurities. The slag reacts with the sulfur and the



1. Walls of refractory bricks, 2. Roof, 3. Melting chamber,
4. Air and gas ducts, 5. Charging doors, 6. Checkerwork

Fig. 6.5 Open hearth furnace

phosphorus in the metal, while the bubbling air causes oxidation of the carbon and silicon. If too much carbon is present in the melt, iron ore is added. The oxygen from the iron oxide burns out the excess carbon. If the carbon content is too low, pig iron is added. This replenishes the carbon. Other alloying elements like Cr, Ni. Co, W, Mo, V etc. are added as needed. Ferromanganese may be added to the crucible after tapping. For acid lining furnace, the charge should be scrap iron and low-phosphorus pig iron. Limestone is required to keep the slag fluid. As described above, the basic lining burns phosphorus, silicon, and carbon. The slag is tapped off by the molten metals being allowed to overflow the sides of the crucible into a slag pot. Oxygen is one of the most important elements used in the reduction of the molten metal. Rust, scale, slag, and limestone are some of the sources of oxygen. Oxygen is introduced into the furnace with oxygen lances through the roof of the furnace. Twice the oxygen input will double the carbon reduction. This increases the steel production of the furnace.

6.6 PIT FURNACE

Pit furnace is a type of a furnace bath which is installed in the form of a pit and is used for melting small quantities of ferrous and non ferrous metals for production of castings. It is provided with refractory inside and chimney at the top. Generally coke is used as fuel. It is provided with refractory lining inside and chimney at the top. Natural and artificial draught can be used for increasing the capability towards smooth operation of the furnace. Fig. 6.6 shows the typical pit furnace.

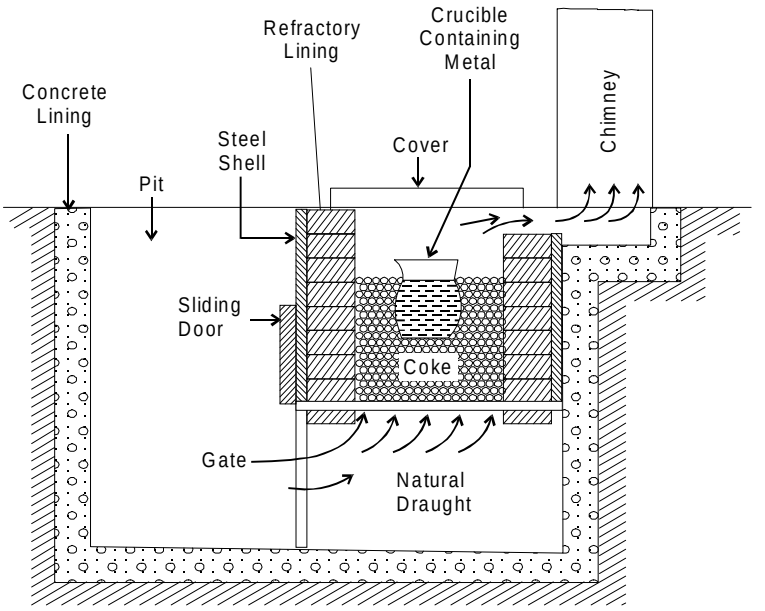


Fig. 6.6 Pit furnace

6.7 CORELESS TYPE INDUCTION FURNACE

It is also called high frequency induction furnace. It consists of refractory crucible placed centrally inside a water cooled copper coil. Fig. 6.7 represent the construction and working of this type of furnace.

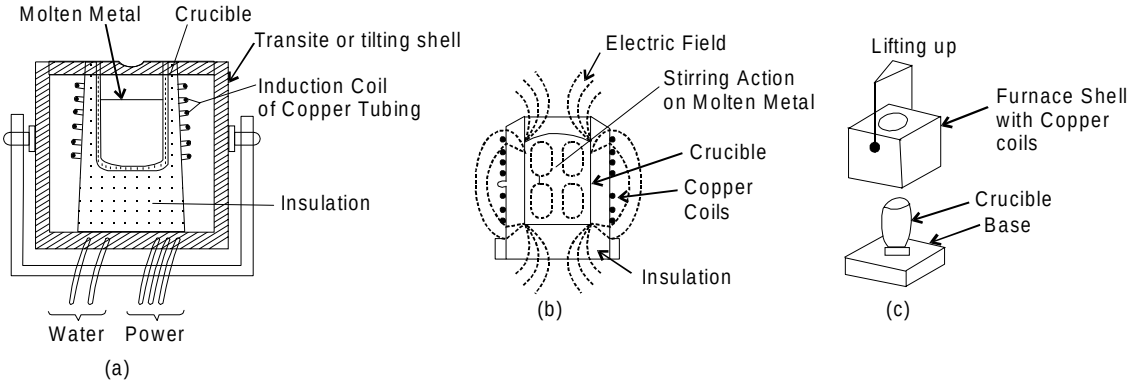


Fig. 6.7 Coreless type induction furnace

6.8 AIR FURNACE

This furnace is also known as puddling or reverbratory furnace. It is used for making wrought iron. Fig 6.8 shows the construction of this type of furnace.

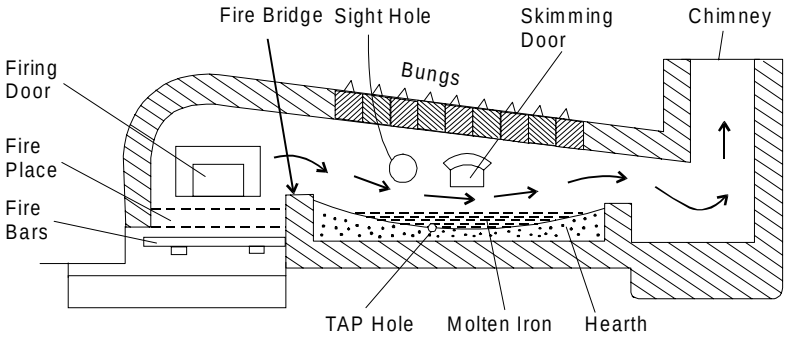


Fig. 6.8 Air furnace

6.9 METHODS OF MEASURING TEMPERATURE

Furnace temperature is measured by following methods namely (i) Electrical pyrometers (2) Thermo electric pyrometers (3) Radiation pyrometers (4) Optical pyrometers and (5) Photo-electric cells.

An important radiation pyrometer is discussed as under.

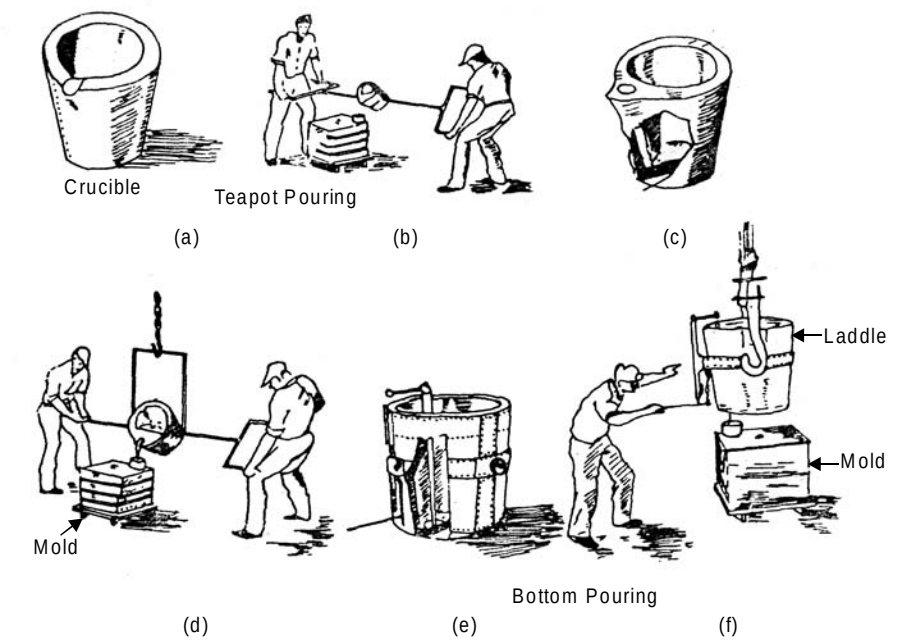


Fig. 6.9 Pouring practices

6.9.1 Radiation Pyrometer

Radiation pyrometer is a temperature device by which the temperature of hot body is measured by measuring the intensity of total heat and light radiation emitted by a hot body. A radiation pyrometer works on the principle of focusing the energy from all wave lengths of radiation upon a sensitive element thus causing a force to be developed in the element which may be

a resistance pyrometer or a thermo couple. All the radiations are concentrated by concave mirror upon the hot junction of a thermo couple. Mirror placed in inclined position is used to indicate whether correct focus can be obtained.

6.10 POURING PRACTICES

Molten metal is collected in ladles from furnaces and skimmed properly before pouring into the mould. Some of the pouring practices are shown in Fig 6.9.

6.10 QUESTIONS

1 What are the general principles of the melting practice?
2 What important factors are considered during melting?
3 What are the factors which govern the selection of a suitable type of furnace for melting a particular metal?
4 What characteristics a refractory material should possess to make it suitable for use in furnaces? How many types of refractory are there?
5 Sketch a blast furnace. Describe its construction and working.
6 Make a neat sketch of a cupola, indicating its various zones and describe the following:
   (*i*) Construction
   (*ii*) Preparation before operations
   (*iii*) Charging method
   (*iv*) Different zones and their functions
   (*v*) Operation
   (*vi*) Advantages
   (*vii*) Limitations and
   (*viii*) Application.
7 What do you mean by basic and acid cupolas? Where each type is preferred and why?
8 How is air requirement for cupola calculated
9 Why is the flux used during melting of metals in cupola?
10 How do you determine the thermal efficiency of a cupola furnace?
11 How will you specify a cupola furnace?
12 What necessary precautions are required in operating the cupola?
13 What are the expected gains in or losses of the various constituents of metal charge during melting and how are these constituents controlled?
14 Why does a cupola sometimes get jammed up? How can it be prevented?
15 Explain with the help of neat sketches the construction and working of the following types of crucible furnaces: (a) A coal fired pit furnace, (b) An oil fired tilting furnace, and (c) A gas fired crucible furnace
16 What are crucible furnaces? Where are they preferred and why?
17 What are the different types of electric furnaces? Describe anyone of them.
18 Describe crucible furnaces.
19 Write short notes on the following:
   (*a*) Open-hearth furnace and (*b*) Resistance furnace.

20 What is refining?
21 What are the different types of pouring ladles?
22 Describe the construction working and uses of core less type induction furnace.
23 What do you understand by fluxing?
24 Name the different types of fluxes, arid describe anyone of them.
25 Describe the purpose for using the pyrometers in melting practice.

7
CHAPTER

PROPERTIES AND TESTING OF METALS

7.1 PROPERTIES OF METALS

The important properties of an engineering material determine the utility of the material which influences quantitatively or qualitatively the response of a given material to imposed stimuli and constraints. The various engineering material properties are given as under.

1. Physical properties
2. Chemical properties
3. Thermal properties
4. Electrical properties
5. Magnetic properties
6. Optical properties, and
7. Mechanical properties

These properties of the material are discussed as under.

7.1.1 Physical Properties

The important physical properties of the metals are density, color, size and shape (dimensions), specific gravity, porosity, luster etc. Some of them are defined as under.

1. Density

Mass per unit volume is called as density. In metric system its unit is kg/mm^3. Because of very low density, aluminium and magnesium are preferred in aeronautic and transportation applications.

2. Color

It deals the quality of light reflected from the surface of metal.

3. Size and shape

Dimensions of any metal reflect the size and shape of the material. Length, width, height, depth, curvature diameter etc. determines the size. Shape specifies the rectangular, square, circular or any other section.

4. Specific Gravity

Specific gravity of any metal is the ratio of the mass of a given volume of the metal to the mass of the same volume of water at a specified temperature.

5. Porosity

A material is called as porous or permeable if it has pores within it.

7.1.2 Chemical Properties

The study of chemical properties of materials is necessary because most of the engineering materials, when they come in contact with other substances with which they can react, suffer from chemical deterioration of the surface of the metal. Some of the chemical properties of the metals are corrosion resistance, chemical composition and acidity or alkalinity. Corrosion is the gradual deterioration of material by chemical reaction with its environment.

7.1.3 Thermal Properties

The study of thermal properties is essential in order to know the response of metal to thermal changes i.e. lowering or raising of temperature. Different thermal properties are thermal conductivity, thermal expansion, specific heat, melting point, thermal diffusivity. Some important properties are defined as under.

Melting Point

Melting point is the temperature at which a pure metal or compound changes its shape from solid to liquid. It is called as the temperature at which the liquid and solid are in equilibrium. It can also be said as the transition point between solid and liquid phases. Melting temperature depends on the nature of inter-atomic and intermolecular bonds. Therefore higher melting point is exhibited by those materials possessing stronger bonds. Covalent, ionic, metallic and molecular types of solids have decreasing order of bonding strength and melting point. Melting point of mild steel is 1500°C, of copper is 1080°C and of Aluminium is 650°C.

7.1.4 Electrical Properties

The various electrical properties of materials are conductivity, temperature coefficient of resistance, dielectric strength, resistivity, and thermoelectricity. These properties are defined as under.

1. Conductivity

Conductivity is defined as the ability of the material to pass electric current through it easily i.e. the material which is conductive will provide an easy path for the flow of electricity through it.

2. Temperature Coefficient of Resistance

It is generally termed as to specify the variation of resistivity with temperature.

3. Dielectric Strength

It means insulating capacity of material at high voltage. A material having high dielectric strength can withstand for longer time for high voltage across it before it conducts the current through it.

4. Resistivity

It is the property of a material by which it resists the flow of electricity through it.

5. Thermoelectricity

If two dissimilar metals are joined and then this junction is heated, a small voltage (in the milli-volt range) is produced, and this is known as thermoelectric effect. It is the base of the thermocouple. Thermo -couples are prepared using the properties of metals.

7.1.5 Magnetic Properties

Magnetic properties of materials arise from the spin of the electrons and the orbital motion of electrons around the atomic nuclei. In certain atoms, the opposite spins neutralize one another, but when there is an excess of electrons spinning in one direction, magnetic field is produced. Many materials except ferromagnetic material which can form permanent magnet, exhibit magnetic affects only when subjected to an external electro-magnetic field. Magnetic properties of materials specify many aspects of the structure and behavior of the matter. Various magnetic properties of the materials are magnetic hysteresis, coercive force and absolute permeability which are defined as under.

1. Magnetic Hysteresis

Hysteresis is defined as the lagging of magnetization or induction flux density behind the magnetizing force or it is that quality of a magnetic substance due to energy is dissipated in it on reversal of its magnetism. Below Curie temperature, magnetic hysteresis is the rising temperature at which the given material ceases to be ferromagnetic, or the falling temperature at which it becomes magnetic. Almost all magnetic materials exhibit the phenomenon called hysteresis.

2. Coercive Force

It is defined as the magnetizing force which is essential to neutralize completely the magnetism in an electromagnet after the value of magnetizing force becomes zero.

3. Absolute Permeability

It is defined as the ratio of the flux density in a material to the magnetizing force producing that flux density. Paramagnetic materials possess permeability greater than one whereas di-magnetic materials have permeability less than one.

7.1.6 Optical Properties

The main optical properties of engineering materials are refractive index, absorptivity, absorption co-efficient, reflectivity and transmissivity. Refractive index is an important optical property of metal which is defined as under.

Refractive Index

It is defined as the ratio of velocity of light in vacuum to the velocity of a material. It can also be termed as the ratio of sine of angle of incidence to the sine of refraction.

7.1.7 Mechanical Properties

Under the action of various kinds of forces, the behavior of the material is studied that measures the strength and lasting characteristic of a material in service. The mechanical properties of materials are of great industrial importance in the design of tools, machines and

structures. Theses properties are structure sensitive in the sense that they depend upon the crystal structure and its bonding forces, and especially upon the nature and behavior of the imperfections which- exist within the crystal itself or at the grain boundaries. The mechanical properties of the metals are those which are associated with the ability of the material to resist mechanical forces and load. The main mechanical properties of the metal are strength, stiffness, elasticity, plasticity, ductility, malleability, toughness, brittleness, hardness, formability, castability and weldability. These properties can be well understood with help of tensile test and stress strain diagram. The few important and useful mechanical properties are explained below.

1. Elasticity

It is defined as the property of a material to regain its original shape after deformation when the external forces are removed. It can also be referred as the power of material to come back to its original position after deformation when the stress or load is removed. It is also called as the tensile property of the material.

2. Proportional limit

It is defined as the maximum stress under which a material will maintain a perfectly uniform rate of strain to stress. Though its value is difficult to measure, yet it can be used as the important applications for building precision instruments, springs, etc.

3. Elastic limit

Many metals can be put under stress slightly above the proportional limit without taking a permanent set. The greatest stress that a material can endure without taking up some permanent set is called elastic limit. Beyond this limit, the metal does not regain its original form and permanent set will occurs.

4. Yield point

At a specific stress, ductile metals particularly ceases, offering resistance to tensile forces. This means, the metals flow and a relatively large permanent set takes place without a noticeable increase in load. This point is called yield point. Certain metals such as mild steel exhibit a definite yield point, in which case the yield stress is simply the stress at this point.

5. Strength

Strength is defined as the ability of a material to resist the externally applied forces with breakdown or yielding. The internal resistance offered by a material to an externally applied force is called stress. The capacity of bearing load by metal and to withstand destruction under the action of external loads is known as strength. The stronger the material the greater the load it can withstand. This property of material therefore determines the ability to withstand stress without failure. Strength varies according to the type of loading. It is always possible to assess tensile, compressive, shearing and torsional strengths. The maximum stress that any material can withstand before destruction is called its ultimate strength. The tenacity of the material is its ultimate strength in tension.

6. Stiffness

It is defined as the ability of a material to resist deformation under stress. The resistance of a material to elastic deformation or deflection is called stiffness or rigidity. A material that suffers slight or very less deformation under load has a high degree of stiffness or rigidity. For instance suspended beams of steel and aluminium may both be strong enough to carry the required load but the aluminium beam will “sag” or deflect further. That means, the steel

beam is stiffer or more rigid than aluminium beam. If the material behaves elastically with linear stress-strain relationship under Hooks law, its stiffness is measured by the Young's modulus of elasticity (E). The higher is the value of the Young's modulus, the stiffer is the material. In tensile and compressive stress, it is called modulus of stiffness or "modulus of elasticity"; in shear, the modulus of rigidity, and this is usually 40% of the value of Young's modulus for commonly used materials; in volumetric distortion, the bulk modulus.

7. Plasticity

Plasticity is defined the mechanical property of a material which retains the deformation produced under load permanently. This property of the material is required in forging, in stamping images on coins and in ornamental work. It is the ability or tendency of material to undergo some degree of permanent deformation without its rupture or its failure. Plastic deformation takes place only after the elastic range of material has been exceeded. Such property of material is important in forming, shaping, extruding and many other hot or cold working processes. Materials such as clay, lead, etc. are plastic at room temperature and steel is plastic at forging temperature. This property generally increases with increase in temperature of materials.

8. Ductility

Ductility is termed as the property of a material enabling it to be drawn into wire with the application of tensile load. A ductile material must be strong and plastic. The ductility is usually measured by the terms, percentage elongation and percent reduction in area which is often used as empirical measures of ductility. The materials those possess more than 5% elongation are called as ductile materials. The ductile material commonly used in engineering practice in order of diminishing ductility are mild steel, copper, aluminium, nickel, zinc, tin and lead.

9. Malleability

Malleability is the ability of the material to be flattened into thin sheets under applications of heavy compressive forces without cracking by hot or cold working means. It is a special case of ductility which permits materials to be rolled or hammered into thin sheets. A malleable material should be plastic but it is not essential to be so strong. The malleable materials commonly used in engineering practice in order of diminishing malleability are lead, soft steel, wrought iron, copper and aluminium. Aluminium, copper, tin, lead, steel, etc. are recognized as highly malleable metals.

10. Hardness

Hardness is defined as the ability of a metal to cut another metal. A harder metal can always cut or put impression to the softer metals by virtue of its hardness. It is a very important property of the metals and has a wide variety of meanings. It embraces many different properties such as resistance to wear, scratching, deformation and machinability etc.

11. Brittleness

Brittleness is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. The materials having less than 5% elongation under loading behavior are said to be brittle materials. Brittle materials when subjected to tensile loads, snap off without giving any sensible elongation. Glass, cast iron, brass and ceramics are considered as brittle material.

12. Creep

When a metal part when is subjected to a high constant stress at high temperature for a longer period of time, it will undergo a slow and permanent deformation (in form of a crack which may further propagate further towards creep failure) called creep.

13. Formability

It is the property of metals which denotes the ease in its forming in to various shapes and sizes. The different factors that affect the formability are crystal structure of metal, grain size of metal hot and cold working, alloying element present in the parent metal. Metals with smal1 grain size are suitable for shallow forming while metal with size are suitable for heavy forming. Hot working increases formability. Low carbon steel possesses good formability.

14. Castability

Castability is defined as the property of metal, which indicates the ease with it can be casted into different shapes and sizes. Cast iron, aluminium and brass are possessing good castability.

15. Weldability

Weldability is defined as the property of a metal which indicates the two similar or dissimilar metals are joined by fusion with or without the application of pressure and with or without the use of filler metal (welding) efficiently. Metals having weldability in the descending order are iron, steel, cast steels and stainless steels.

7.2 RECOVERY, RECRYSTALLISATION AND GRAIN GROWTH

When metal is subjected to hot working and cold working processes, plastic deformation occurs which is an important phenomenon. Plastic deformation of metal distorts the crystal lattice. It breaks up the blocks of initial equiaxed grains to produce fibrous structure and increases the energy level of metal. Deformed metal, during comparison with its un-deformed state, is in non-equilibrium, thermodynamically unstable state. Therefore, spontaneous processes occur in strain-hardened metal, even at room temperature that brings it into a more stable condition. When the temperature of metal is increased, the metal attempts to approach equilibrium through three processes: (i) recovery, (ii) recrystallisation, and (iii) grain growth. Fig.7.1 reflects the recovery, recrystallisation and grain growth and the main property changes in each region.

7.2.1 Recovery

When a strain-hardened metal is heated to a low temperature, the elastic distortions of the crystal lattice are reduced due to the increase in amplitude of thermal oscillation of the atoms. This heating will decrease the strength of the strain-hardened metal but there is an increase in the elastic limit and ductility of metal, though they will not react the values possessed by the initial material before strain-hardening. No changes in microstructure of metal are observed in this period. The partial restoration of the original characteristics, produced by reducing the distortion of the crystal lattice without remarkable changes in microstructure, is called recovery. At the initial state, the rate of the recovery is fastest and it drops off at longer times at given temperature. Hence the amount of recovery that occurs in a practical time increases with increasing temperature. The individual characteristic recover at different rates and gain various degrees of completion in a given cold worked metal.

7.2.2 Recrystallisation

Formation of new equiaxed grains in the heating process of metal, instead of the oriented fibrous structure of the deformed metal, is called recrystallisation. The process of recrystallisation is illustrated through Fig. 7.1. The first effect of heating of metal is to form new minute grains and these rapidly enlarge until further growth is restricted by grain meeting another. The original system of grains go out of the picture and the new crystallized structure is formed in the metal. Recrystallisation does not produce new structures however it produces new grains or crystals of the same structure in the metal. It consists in having the atoms of the deformed metal overcome the bonds of the distorted lattice, the formation of nuclei of equiaxed grains and subsequent growth of these grains due to transfer of atoms from deformed to un-deformed crystallites. Finer grains get refined and acquire a shape resembling fibres. The temperature at which crystallization starts, that is new grains are formed, is called recrystallisation temperature. Recrystallisation temperature is also defined as that temperature at which half of the cold worked material will recrystallise in 60 minutes.

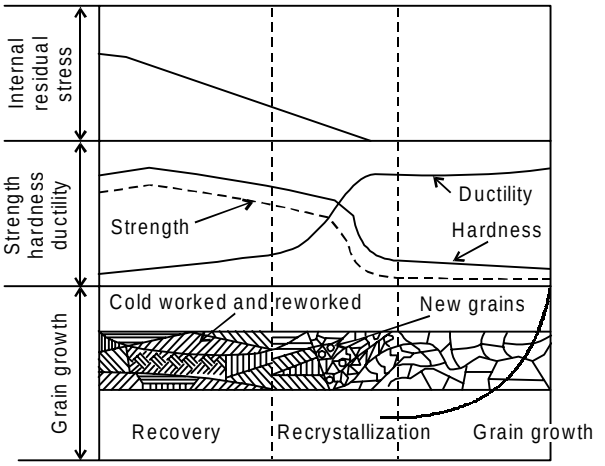


Fig. 7.1 Recovery, recrystalisation and grain growth

7.2.3 Grain Growth

On recrystallisation of metal, the grains are smaller and somewhat regular in shape. The grains in metal will grow if the temperature is high enough or if the temperature is allowed to exceed the minimum required for recrystallisation and this growth of grain is the result of a tendency to return to more stable and larger state. It appears to depend primarily on the shape of the grain. For any temperature above the recrystallization temperature, normally there is practical maximum size at which the grains will reach equilibrium and cease to grow significantly. However, there are certain kinds of abnormal grains growth in metal that occur as a result of applied or residual gradients of strain due to non-uniform impurity distribution, and which permits growing very large single grain in metal.

7.3 TESTING OF METALS

Metal testing is accomplished for the purpose of for estimating the behavior of metal under loading (tensile, compressive, shear, tortion and impact, cyclic loading etc.) of metal and for

providing necessary data for the product designers, equipment designers, tool and die designers and system designers. The material behavior data under loading is used by designers for design calculations and determining weather a metal can meet the desired functional requirements of the designed product or part. Also, it is very important that the material shall be tested so that their mechanical properties especially their strength can be assessed and compared. Therefore the test procedure for developing standard specification of materials has to be evolved. This necessitates both destructive and non-destructive testing of materials. Destructive tests of metal include various mechanical tests such as tensile, compressive, hardness, impact, fatigue and creep testing. A standard test specimen for tensile test is shown in Fig. 7.2. Non-destructive testing includes visual examination, radiographic tests, ultrasound test, liquid penetrating test and magnetic particle testing.

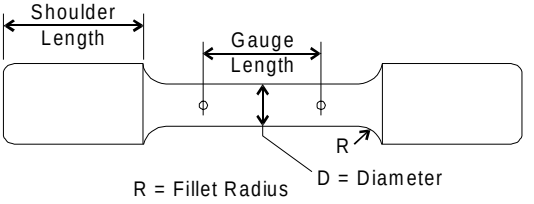


Fig. 7.2 Tensile test specimen

7.3.1 Tensile test

A tensile test is carried out on standard tensile test specimen in universal testing machine. Fig. 7.3 shows a schematic set up of universal testing machine reflecting the test specimen griped between two cross heads. Fig. 7.4 shows the stress strain curve for ductile material. Fig. 7.5 shows the properties of a ductile material. Fig. 7.6 shows the stress strain curves for wrought iron and steels. Fig. 7.7 shows the stress strain curve for non ferrous material.

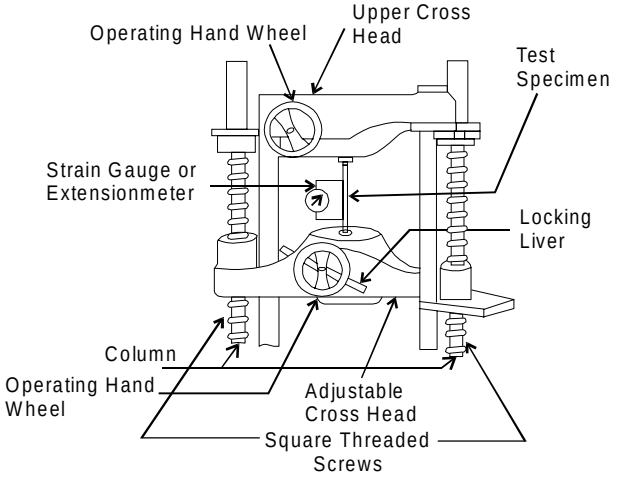


Fig. 7.3 Schematic universal testing machine

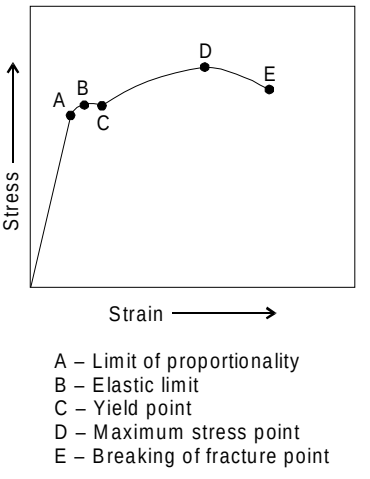


Fig. 7.4 Stress strain curve for ductile material

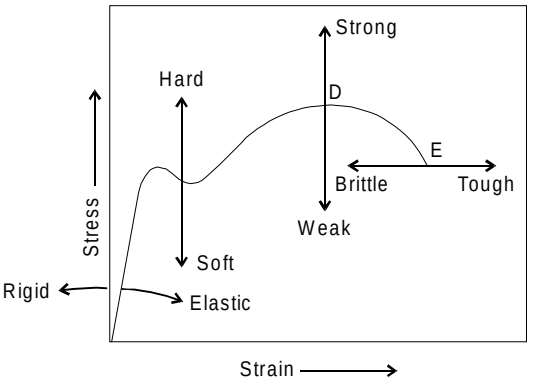


Fig. 7.5 Properties of a ductile material

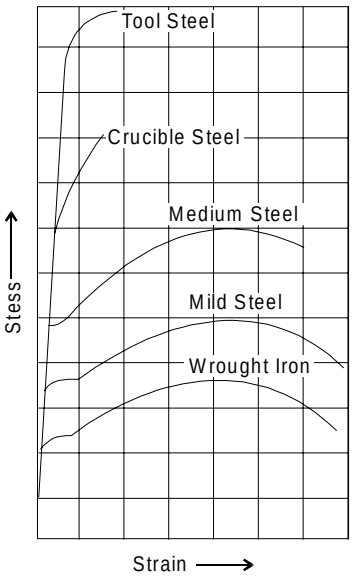


Fig. 7.6 Stress strain curves for wrought iron and steel

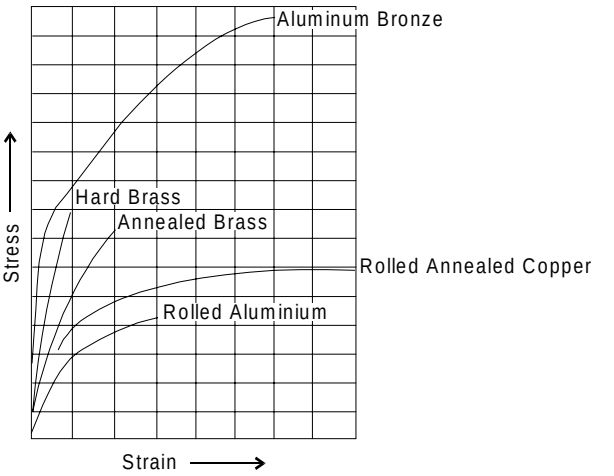


Fig. 7.7 Stress strain curves for non-ferrous material

7.3.2 Compression Test

Compression test is reverse of tensile test. This test can also be performed on a universal testing machine. In case of compression test, the specimen is placed bottom crossheads. After that, compressive load is applied on to the test specimen. This test is generally performed for testing brittle material such as cast iron and ceramics etc. Fig. 7.8 shows the schematic compression test set up on a universal testing machine. The following terms have been deduced using figures pertaining to tensile and compressive tests of standard test specimen.

Hook's Law

Hook's law states that when a material is loaded within elastic limit (up to proportional limit), stress is proportional to strain.

Strain

Strain is the ratio of change in dimension to the original dimension.

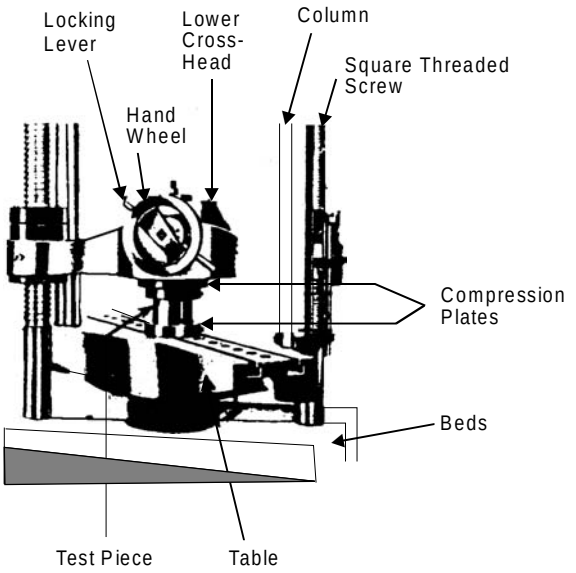


Fig. 7.8 Schematic compression test set up on a universal testing machine

Tensile Strain

The ratio of increase in length to the original length is known as tensile strain.

Compressive Strain

The ratio of decrease in length to the original length is known as compressive strain.

Modulus of Elasticity

The ratio of tensile stress to tensile strain or compressive stress to compressive strain is called modulus of elasticity. It is denoted by E. It is also called as Young's modulus of elasticity.

E = Tensile Stress/Tensile Strain

Modulus of Rigidity

The ratio of sheer stress to shear strain is called modulus of rigidity. It is denoted by G.

G = Shear Stress/Shear Strain

Bulk Modulus

The ratio of direct stress to the volumetric strain (ratio of change in volume to the original volume is known as volumetric strain) is called Bulk modulus (denoted by K).

K = Direct stress/volumetric strain

Linear and Lateral Strain

When a body is subjected to tensile force its length increases and the diameter decreases. So when a test specimen of metal is stressed, one deformation is in the direction of force which is called linear strain and other deformation is perpendicular to the force called lateral strain.

Poisson's Ratio

The ratio of lateral strain to linear strain in metal is called poisson's ratio. Its value is constant for a particular material but varies for different materials.

Proof Resilience

The maximum amount of energy which can be stored in an elastic limit is known as proof resilience.

Modulus of Resilience

The proof resilience per unit volume of a material is modulus of resilience or elastic toughness.

7.3.3 Testing of Hardness

It is a very important property of the metals and has a wide variety of meanings. It embraces many different properties such as resistance to wear, scratching, deformation and machinability etc. It also means the ability of a metal to cut another metal. The hardness of a metal may be determined by the following tests.

(*a*) Brinell hardness test
(*b*) Rockwell hardness test
(*c*) Vickers hardness (also called Diamond Pyramid) test
(*d*) Shore scleroscope

Fig. 7.9 shows Rockwell hardness testing machine.

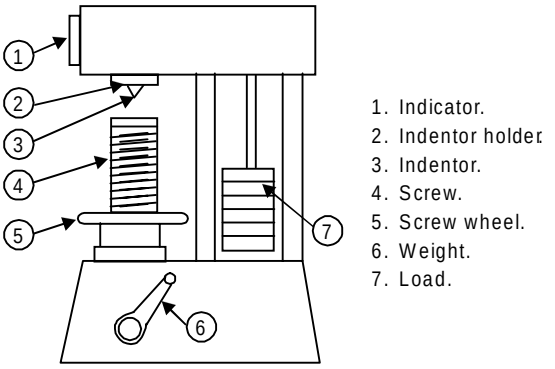


Fig. 7.9 Rockwell hardness testing machine

7.3.4 Testing of Impact Strength

When metal is subjected to suddenly applied load or stress, it may fail. In order to assess the capacity of metal to stand sudden impacts, the impact test is employed. The impact test measures the energy necessary to fracture a standard notched bar by an impulse load and as such is an indication of the notch toughness of the material under shock loading. Izod test and the Charpy test are commonly performed for determining impact strength of materials. These methods employ same machine and yield a quantitative value of the energy required to fracture a special V notch shape metal. The most common kinds of impact test use notched specimens loaded as beams. V notch is generally used and it is get machined to standard specifications with a special milling cutter on milling machine in machine shop. The beams may be simply loaded (Charpy test) or loaded as cantilevers (Izod test). The function of the

V notch in metal is to ensure that the specimen will break as a result of the impact load to which it is subjected. Without the notch, many alloys would simply bend without breaking, and it would therefore be impossible to determine their ability to absorb energy. It is therefore important to observe that the blow in Charpy test is delivered at a point directly behind the notch and in the Izod test the blow is struck on the same side of the notch towards the end of the cantilever. Fig. 7.10 shows the impact testing set up arrangement for charpy test. The specimen is held in a rigid vice or support and is struck a blow by a traveling pendulum that fractures or severely deforms the notched specimen. The energy input in this case is a function of the height of fall and the weight of the pendulum used in the test setup. The energy remaining after fracture is determined from the height of rise of the pendulum due to inertia and its weight. The difference between the energy input and the energy remaining represents the energy absorbed by the standard metal specimen. Advance testing setups of carrying out such experiments are generally equipped with scales and pendulum-actuated pointers, which provide direct readings of energy absorption.

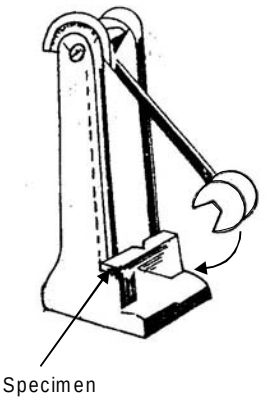


Fig. 7.10 Schematic impact testing machine setup

7.3.5 Testing of Fatique

Material subjected to static and cyclic loading, yield strength is the main criterion for product design. However for dynamic loading conditions, the fatigue strength or endurance limit of a material is used in main criteria used for designing of parts subjected to repeated alternating stresses over an extended period of time. Fig 7.11 shows a fatigue test set up determining the fatigue strength of material. The fatigue test determines the stresses which a sample of material of standard dimensions can safely endure for a given number of cycles. It is performed on a test specimen of standard metal having a round cross-section, loaded at two points as a rotating simple beam, and supported at its ends. The upper surface of such a standard test specimen is always in compression and the lower surface is always in tension. The maximum stress in metal always occurs at the surface, halfway along the length of the standard test specimen, where the cross section is minimum. For every full rotation of the specimen, a point in the surface originally at the top centre goes alternately from a maximum in compression to a maximum in tension and then back to the same maximum in compression. Standard test specimens are tested to failure using different loads, and the number of cycles before failure is noted for each load. The results of such tests are recorded on graphs of applied stress against the logarithm of the number of cycles to failure. The curve is known as S-N curve.

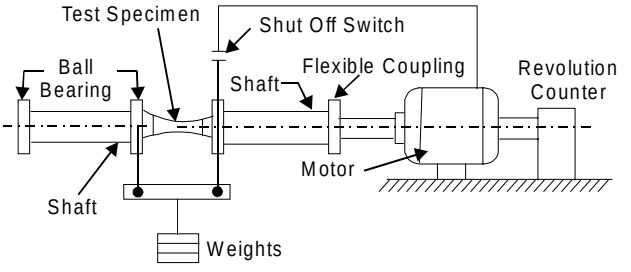


Fig. 7.11 Schematic fatigue test setup

7.3.6 Testing of Creep

Metal part when is subjected to a high constant stress at high temperature for a longer period of time, it will undergo a slow and permanent deformation (in form of a crack which may further propagate further towards creep failure) called creep. Creep is time dependent phenomena of metal failure at high constant stress and at high temperature such subjecting of at steam turbine blade. A schematic creep testing setup is shown in Fig. 7.12. Test is carried out up to the failure of the test specimen. A creep curve for high temperature and long time creep is shown in Fig. 7.13. The curve shows different portions of the primary secondary and tertiary creep which ends at fracture in metals.

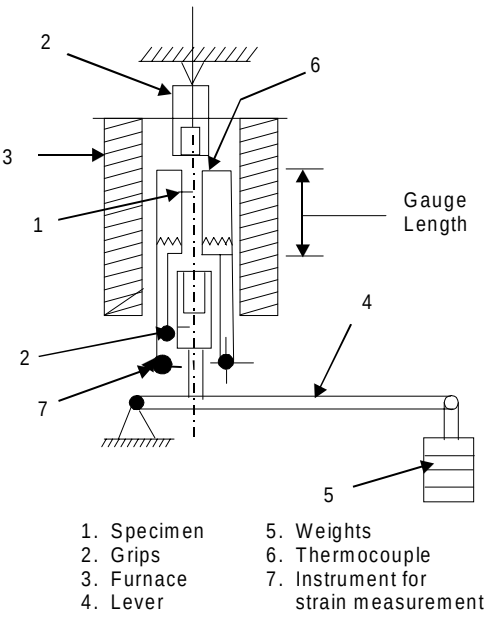


Fig. 7.12 Schematic creep testing setup

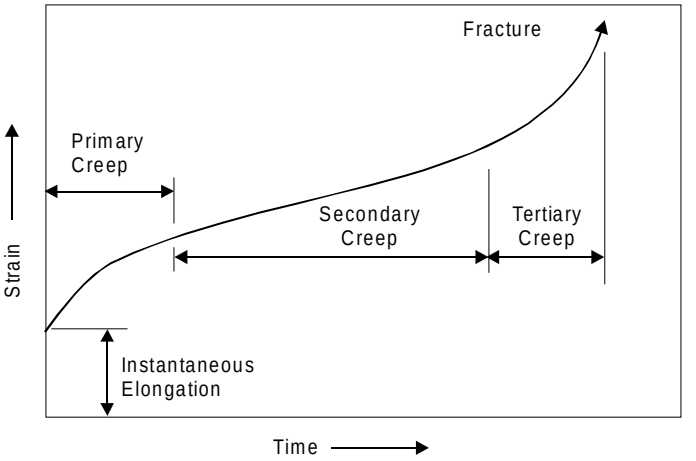


Fig. 7.13 Creep curve for a high temperature and long time creep test

7.4 CHOICE OF MATERIALS FOR THE ENGINEERING APPLICATONS

The choice of materials for the engineering purposes depends upon the following factors:

1 Availability of the materials,

2 Properties needed for meeting the functional requirements,

3 Suitability of the materials for the working conditions in service, and

4 The cost of the materials.

7.5 QUESTIONS

1 Classify the various properties of engineering materials.
2 Explain various physical properties of engineering materials.
3 Explain briefly thermal conductivity and thermal expansion.
4 Explain various mechanical properties of engineering materials.
5 Define various chemical properties of engineering materials.
6 Explain various electrical properties of engineering materials.
7 Define various optical properties of engineering materials.
8 Explain various magnetic, chemical and optical properties of engineering materials.
9 Write short notes on the following:
(*a*) Elasticity (*b*) Plasticity (*c*) Fatigue (*d*) Creep (*e*) Toughness.
10 Write short notes on the following:
(*a*) Malleability, (*b*) Brittleness, (*c*) Yield point, (*d*) Ductility, (*e*) Wear resistance and (*f*) Toughness.
11 Write short notes on the following:
(*a*) Machinability, (*b*) Hardness, (*c*) Stiffness, (*d*) Weldabilty, (*e*) Formability, (*f*) Ductility and (*g*) Brittleness.

8
CHAPTER

HEAT TREATMENT

8.1 INTRODUCTION

Heat treatment is a heating and cooling process of a metal or an alloy in the solid state with the purpose of changing their properties. It can also be said as a process of heating and cooling of ferrous metals especially various kinds of steels in which some special properties like softness, hardness, tensile-strength, toughness etc, are induced in these metals for achieving the special function objective. It consists of three main phases namely (*i*) heating of the metal (*ii*) soaking of the metal and (*iii*) cooling of the metal. The theory of heat treatment is based on the fact that a change takes place in the internal structure of metal by heating and cooling which induces desired properties in it. The rate of cooling is the major controlling factor. Rapid cooling the metal from above the critical range, results in hard structure. Whereas very slow cooling produces the opposite affect i.e. soft structure. In any heat treatment operation, the rate of heating and cooling is important. A hard material is difficult to shape by cutting, forming, etc. During machining in machine shop, one requires machineable properties in job piece hence the properties of the job piece may requires heat treatment such as annealing for inducing softness and machineability property in workpiece. Many types of furnaces are used for heating heat treatment purposes. The classification of such heat treatment furnaces is given as under.

8.2 HEAT TREATMENT FURNACES

8.2.1 Hearth Furnaces

These furnaces are heated by fuel which may be coke, coal, gas (town, blast or natural) and fuel oil. They can also be operated electrically. They are generally of two types.

(*a*) Stationary type

It consists of four types

(1) Direct fuel fired furnace

(2) Indirect fuel fired furnace

(3) Multiple furnace

(4) Re-circulation furnace

(*b*) Movable type

It consists of two types

(1) The car bottom type

(2) The rotary type

8.2.2 Bath Furnaces

In bath type furnaces, heating may be done using by gas, oil or electricity. These furnaces are further classified as:

(1) Liquid bath type

(2) Salt bath type

(3) Lead bath type

(4) Oil bath type

8.3 CONSTITUENTS OF IRON AND STEEL

Fig. 8.1 shows micro structure of mild steel (0.2-0.3% C). White constituent in this figure is very pure iron or having very low free carbon in iron in form of ferrite and dark patches contain carbon in iron is chemically combined form known as carbide (Cementite). Cementite is very hard and brittle. Now if the dark patches of the above figure are further observed, a substance built up of alternate layer of light and dark patches is reflected in Fig. 8.2. These layers are alternatively of ferrite and cementite. This substance is called as pearlite and is made up of 87% ferrite and 13% cementite. But with increase of carbon content in steel portion of pearlite increases up to 0.8% C. The structure of steel at 0.8% C is entirely of pearlite. However if carbon content in steel is further increased as free constituent up to 1.5% C, such steel will be called as high carbon steel. The micro structure of high carbon steel is depicted in Fig. 8.3.

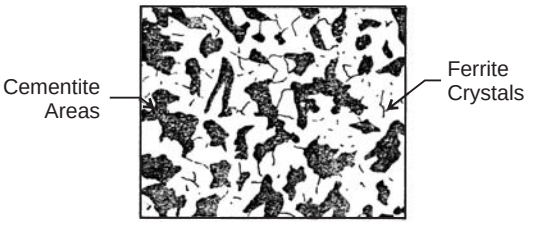


Fig. 8.1 Micro structure of mild steel

Fig. 8.2 Micro structure of pearlitic eutectoid steel

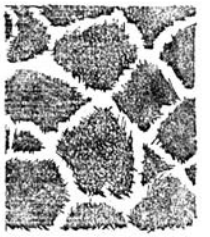


Fig. 8.3 Micro structure of of high carbon steel

8.4 ALLOTROPY OF IRON

In actual practice it is very difficult to trace the cooling of iron from 1600°C to ambient temperature because particular cooling rate is not known. Particular curve can be traced from temperature, time and transformation (TTT) curve. However allotropic changes observed during cooling of pure iron are depicted in Fig. 8.4. When iron is cooled from molten condition up to the solid state, the major allotropic changing occurs which are:

1539-1600°C	Molten-Fe (Liquid state of iron)
1400-1539°C	Delta-Fe (Body centered)

910-1400°C	Gamma-Fe (FCC atomic arrangement and austenite structure)
770- 910°C	Beta-Fe (Body centered-nonmagnetic)
Up to 770°C	Alpha-Fe (BCC atomic arrangement and ferrite structure)

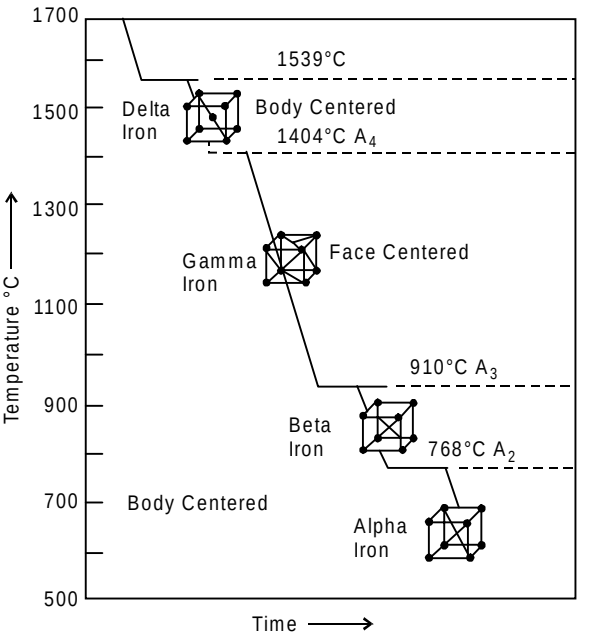


Fig. 8.4 Allotroic changes during cooling of pure iron

(*i*) First changing occurs at l539°C at which formation of delta iron starts.

(*ii*) Second changing takes place at 1404°C and where delta iron starts changes into gamma iron or austenite (FCC structure).

(*iii*) Third changing occurs at 910°C and where gamma iron (FCC structure) starts changes into beta iron (BCC structure) in form of ferrite, leadaburite and austenite.

(*iv*) Fourth changing takes place at 768°C and where beta iron (BCC structure) starts changes into alpha iron in form of ferrite, pearlite and cementite.

Therefore, the temperature points at which such changing takes place into allotropic forms are called critical points. The critical points obtained during cooling are slightly lower than those obtained in heating. The most marked of these range commonly called the point of recalescence and point of decalescence.

8.5 TRANSFORMATION DURING HEATING AND COOLING OF STEEL

When a steel specimen is heated, its temperature rises unless there is change of state or a change in structure. Fig. 8.5 shows heating and cooling curve of steel bearing different structures. Similarly, if heat is extracted, the temperature falls unless there is change in state or a change in structure. This change of structure does not occur at a constant temperature. It takes a sufficient time a range of temperature is required for the transformation. This range is known as transformation range. For example, the portion between the lower critical temperature line and the upper critical temperature line with hypo and hyper eutectoid

steels, in iron carbon equilibrium diagram. This range is also known as critical range. Over heating for too long at a high temperature may lead to excessive oxidation or decarburization of the surface. Oxidation may manifest itself in the form of piece of scale which may be driven into the surface at the work piece if it is going to be forged. If steel is heated, well above the upper critical temperature, large austenite grains form. In other words steel develops undesirable coarse grains structure if cooled slowly to room temperature and it lacks both in ductility and resistance to shock.

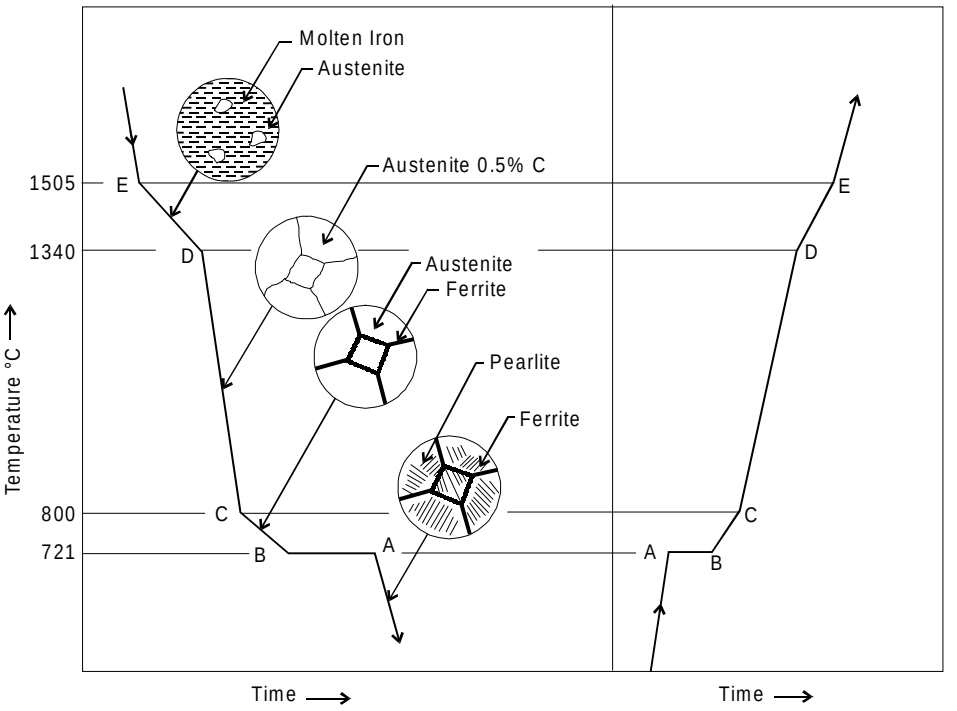


Fig. 8.5 Heating and cooling curve of steel

8.6 IRON-CARBON EQUILIBRIUM DIAGRAM

Fig. 8.6 shows, the Fe-C equilibrium diagram in which various structure (obtained during heating and cooling), phases and microscopic constituents of various kinds of steel and cast iron are depicted. The main structures, significance of various lines and critical points are discussed as under.

8.6.1 Structures in Fe-C-diagram

The main microscopic constituents of iron and steel are as follows:

1. Austenite
2. Ferrite
3. Cementite
4. Pearlite

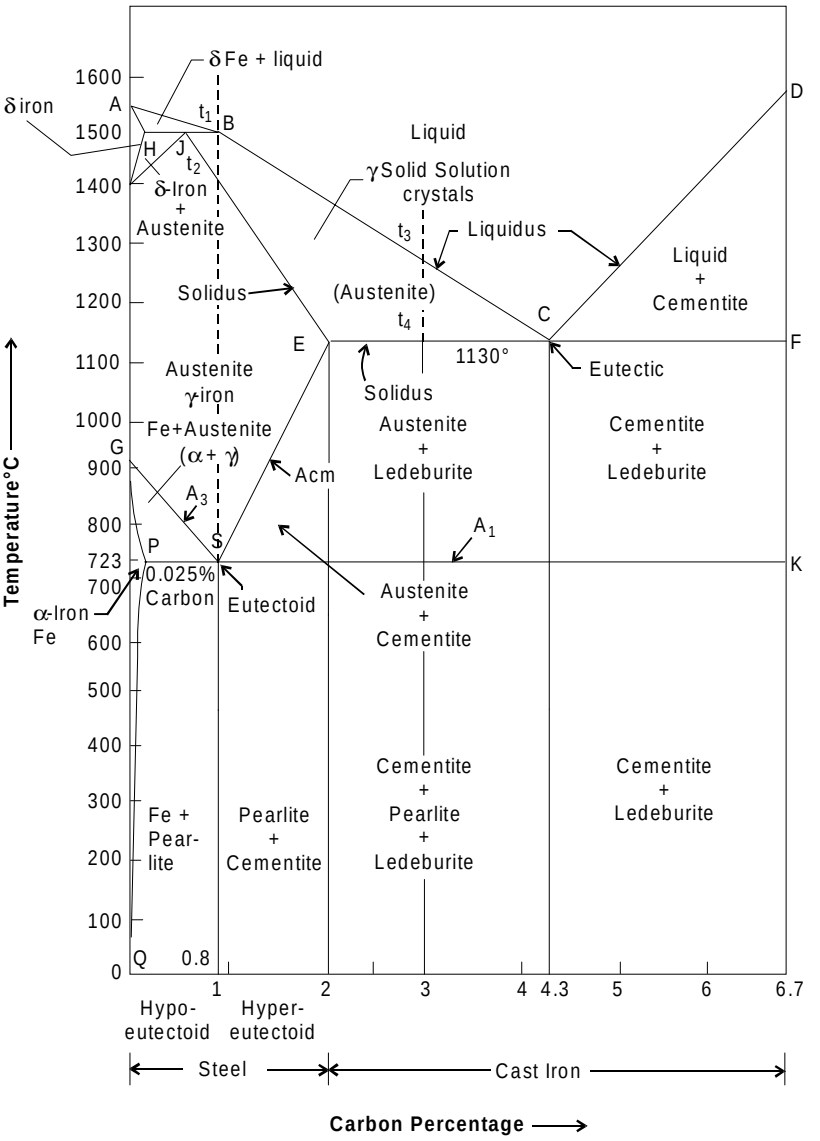


Fig. 8.6 Fe-C equilibrium diagram

8.6.1.1 Austenite

Austenite is a solid solution of free carbon (ferrite) and iron in gamma iron. On heating the steel, after upper critical temperature, the formation of structure completes into austenite which is hard, ductile and non-magnetic. It is able to dissolve large amount of carbon. It is in between the critical or transfer ranges during heating and cooling of steel. It is formed when steel contains carbon up to 1.8% at 1130°C. On cooling below 723°C, it starts transforming into pearlite and ferrite. Austenitic steels cannot be hardened by usual heat treatment methods and are non-magnetic.

8.6.1.2 Ferrite

Ferrite contains very little or no carbon in iron. It is the name given to pure iron crystals which are soft and ductile. The slow cooling of low carbon steel below the critical temperature produces ferrite structure. Ferrite does not harden when cooled rapidly. It is very soft and highly magnetic.

8.6.1.3 Cementite

Cementite is a chemical compound of carbon with iron and is known as iron carbide (Fe3C). Cast iron having 6.67% carbon is possessing complete structure of cementite. Free cementite is found in all steel containing more than 0.83% carbon. It increases with increase in carbon % as reflected in Fe-C Equilibrium diagram. It is extremely hard. The hardness and brittleness of cast iron is believed to be due to the presence of the cementite. It decreases tensile strength. This is formed when the carbon forms definite combinations with iron in form of iron carbides which are extremely hard in nature. The brittleness and hardness of cast iron is mainly controlled by the presence of cementite in it. It is magnetic below 200°C.

8.6.1.4 Pearlite

Pearlite is a eutectoid alloy of ferrite and cementite. It occurs particularly in medium and low carbon steels in the form of mechanical mixture of ferrite and cementite in the ratio of 87:13. Its hardness increases with the proportional of pearlite in ferrous material. Pearlite is relatively strong, hard and ductile, whilst ferrite is weak, soft and ductile. It is built up of alternate light and dark plates. These layers are alternately ferrite and cementite. When seen with the help of a microscope, the surface has appearance like pearl, hence it is called pearlite. Hard steels are mixtures of pearlite and cementite while soft steels are mixtures of ferrite and pearlite.

As the carbon content increases beyond 0.2% in the temperature at which the ferrite is first rejected from austenite drop until, at or above 0.8% carbon, no free ferrite is rejected from the austenite. This steel is called eutectoid steel, and it is the pearlite structure in composition.

As iron having various % of carbon (up to 6%) is heated and cooled, the following phases representing the lines will tell the about the structure of iron, how it charges.

8.6.2 Significance of Transformations Lines

Line ABCD

The line ABCD tells that above this line melting has been completed during heating the iron. The molten metal is purely in the liquidus form. Below this line and above line AHJECF the metal is partially solid and partially liquid. The solid metal is known as austenite. Thus the line ABCD represents temperatures at which melting is considered as completed. Beyond this line metal is totally in molten state. It is not a horizontal line the melting temperature will vary with carbon content.

Line AHJECF

This line tells us that metal starts melting at this temperature. This line is not horizontal and hence the melting temperatures will change with carbon content. Below this line and above line GSEC, the metal is in solid form and having austenite structure.

Line PSK

This line occurs near 723°C and is a horizontal line and is known as lower critical temperature line because transformation of steels starts at, this line. Carbon % has not effect on it that means steel having different % of carbon will transforms at the same temperature. The range above the line up to GSE is known as transformation range. This line tells us the steel having carbon up to 0.8% up to 0.8% will starts transforming from ferrite and pearlite to austenite during heating.

Line ECF

It is a line at temperature 1130°C which tells that for cast iron having % of C from 2% to 4.3%. Below this line and above line SK, Cast iron will have austenite + ledeburite and cementite + ledeburite.

8.6.3 Critical Temperatures

The temperatures at which changes in structure takes place is known as critical temperatures, these are as follows:

1. The temperature along **GSE is known as upper critical temperature**. The temperature along GS during heating as (upper critical temperature) where austenite + alpha iron changes into austenite and vice versa.
2. The temperature along GS during cooling as A_3 where austenite changes into austenite + alpha iron and vice versa during heating.
3. The temperature along line SE during heating as Acm changes into austenite from austenite + cementite and vice versa.
4. The temperature along **PSK is known as lower critical temperature** when pearlite changes into austenite on heating as denoted, by A_1.

8.6.2 Objectives of Heat Treatment

The major objectives of heat treatment are given as under

1. It relieves internal stresses induced during hot or cold working.
2. It changes or refines grain size.
3. It increases resistance to heat and corrosion.
4. It improves mechanical properties such as ductility, strength, hardness, toughness, etc.
5. It helps to improve machinability.
6. It increases wear resistance
7. It removes gases.
8. It improves electrical and magnetic properties.
9. It changes the chemical composition.
10. It helps to improve shock resistance.
11. It improves weldability.

The above objectives of heat treatment may be served by one or more of the following heat treatment processes:

1. Normalizing
2. Anne aling.
3. Hardening.
4. Tempering
5. Case hardening
   (*a*) Carburizing
   (*b*) Cyaniding
   (*c*) Nitriding
6. Surface hardening
   (*a*) Induction hardening,
   (*b*) Flame hardening.

Fig. 8.7 shows the heating temperature ranges for various heat treatment processes.

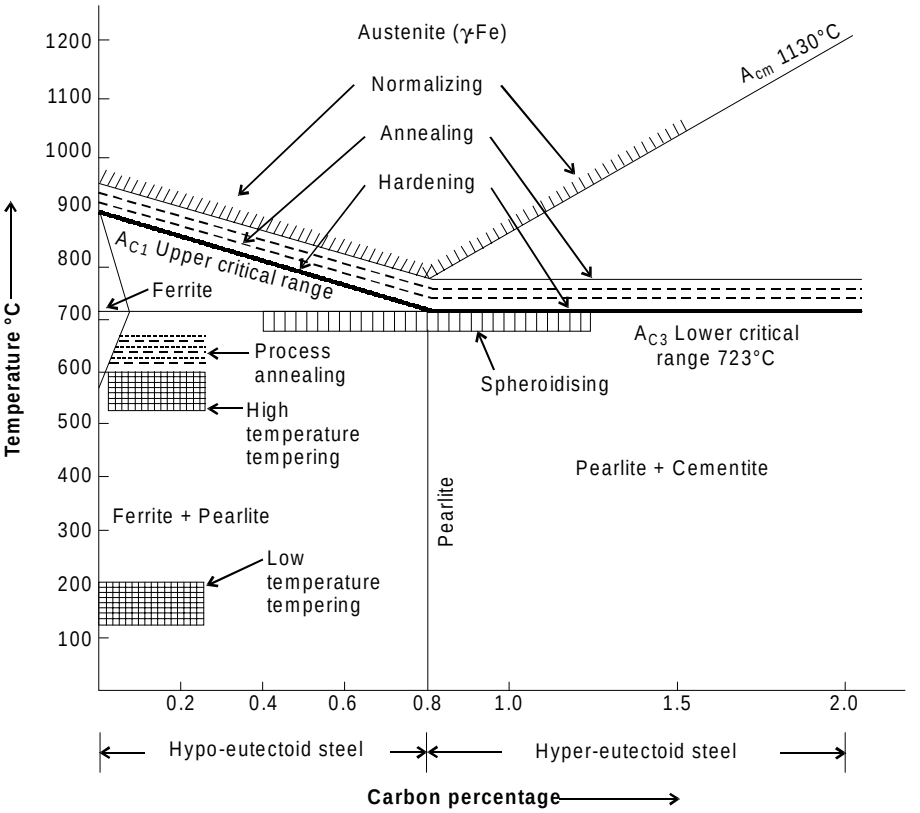


Fig. 8.7 Heating temperature ranges for various heat treatment processes

8.8 NORMALIZING

Normalizing is a defined as softening process in which iron base alloys are heated 40 to 50°C above the upper-critical limit for both hypo and hyper eutectoid steels and held there for a specified period and followed by cooling in still air up to room temperature. Fig 8.7 shows the

heating temperature ranges for normalizing process of both hypo and hyper carbon steel. Fig. 8.8 shows the structure obtained after normalizing of medium carbon steel.

Objectives

1. To soften metals
2. Refine grain structure
3. Improve machinability after forging and rolling
4. improve grain size
5. Improve structure of weld
6. Prepare steel for sub heat treatment

8.9 ANNEALING

It is a softening process in which iron base alloys are heated above the transformation range held there for proper time and then cool slowly (at the of rate of 30 to 150°C per hour) below the transformation range in the furnace itself. Heating is carried out 20°C above upper critical temperature point of steel in case of hypo eutectoid steel and the same degree above the lower critical temperature point in case of type eutectoid steel. Fig 8.7 shows the heating temperature ranges for annealing or softening process of both hypo and hyper carbon steel. Fig. 8.9 shows the structure obtained after annealing of medium carbon steel. The structure of steel on slow cooling changes into ferrite and pearlite for hypo eutectoid steel, pearlite for eutectoid steel and pearlite and cementite for hyper eutectoid steel. The time for holding the article in furnace is ½ to 1 hour. As ferrous metals are heated above the transformation range, austenite structure will be attained at this temperature.

For a particular type of structure specific cooling rate is required to have good annealing properties for free machining. As metal is slowly cooled after heating and holding in and with the furnace and buried in non conducting media such sand, lime or ashes, carbon steels are cooled down at particular rate normally 150-200°C per hour while alloy steel in which austenite is very stable and should be cooled much lower (30°C to 100°C per hour). Very slow cooling is required in annealing to enable austenite to decompose at two degrees of super cooling so as to form a pearlite and ferrite structure in hypo-eutectoid steel, a pearlite structure in eutectoid steel and pearlite and cementite structure in hyper eutectoid steel. In successfully annealed steel, the grains of ferrite are large and regular while pearlite consists of cementite and ferrite. Hypo-eutectoid hot worked steel may under go full annealing to obtain coarse grain structure for free machining. When steel is cold worked the hardness (Brinell hard) considerably increases and ductility decreases slightly. The ductility of steel may be then restored by so called recrystallisation or process annealing.

8.9.1 Objectives of Annealing

The purpose of annealing is to achieve the following

1. Soften the steel.
2. Relieve internal stresses
3. Reduce or eliminate structural in-homogeneity.
4. Refine grain size.
5. Improve machinability.
6. Increase or restore ductility and toughness.

Annealing is of two types

(*a*) Process annealing

(*b*) Full annealing.

In process annealing, ductility is increased with somewhat decrease in internal stresses. In this, metal is heated to temperature some below or close to the lower critical temperature generally it is heated 550°C to 650°C holding at this temperature and it is slowly cooled. This causes completely recrystallisation in steel.

The main purpose of full annealing of steel is to soften it and to refine its grain structure. In this, the hypo-eutectoid steel is heated to a temperature approximately 20° to 30°C above the higher critical temperature and for hypereutectoid steel and tool steel is heated to a temperature 20 to 30°C above the lower critical temperature and this temperature is maintained for a definite time and then slowly cooed very slow1y in the furnace itself.

8.10 SPHEROIDIZATION

It is lowest temperature range of annealing process in which iron base alloys are heated 20 to 40°C below the lower critical temperature, held therefore a considerable period of time e.g. for 2.5 cm diameter piece the time recommended is four-hours. It is then allowed to cool very slowly at room temperature in the furnace itself. Fig 8.7 shows the heating temperature ranges for spheroidizing process of carbon steel. Fig. 8.9 shows the structure obtained after annealing of carbon steel. During this process, the cementite of steel which is in the combined form of carbon becomes globular or spheroidal leaving ferrite in matrix, thus imparting softness to steel. After normalizing of steels, the hardness of the order of 229 BHN and as such machining becomes difficult and hence to improve machining, these are spheroidised first and then machined. This treatment is carried out on steels having 0.6 to 1.4% carbon. The objectives of spheroidising are given as under.

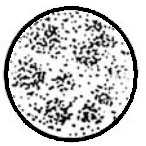


Fig. 8.8 Structure of normalized medium carbon steel

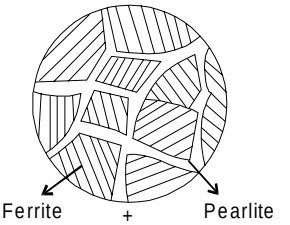


Fig. 8.9 Structure of annealed medium carbon steel

1. To reduce tensile strength
2. To increase ductility
3. To ease machining
4. To impart structure for subsequent hardening process

8.11 COMPARISON BETWEEN ANNEALING AND NORMALISING

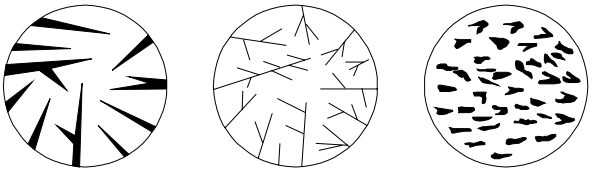
The comparison between annealing and normalizing is given as under in Table 8.1.

Table 8.1 Comparison between Annealing and Normalising

S.No.	Annealing	Normalising
1	In this hypo-eutectoid steel is heated to a temperature approximately 20 to 30°C above temperature the higher critical temperature and for hypereutectoid steel is heated 20 to 30°C above the lower critical temperature.	In this metal is heated 30 to 50°C above higher critical temperature.
2	It gives good results for low and medium carbon steel	It also gives very good results for low and medium carbon steel
3	It gives high ductility	It induces gives higher ultimate strength, yield point and impact strength in ferrous material.
4	It is basically required to soften the metal, to improve machinability, to increase ductility, improve, to refine grain size.	It is basically required to refine grain size, improve structure of weld, to relieve internal stresses.

8.12 HARDENING

Hardening is a hardness inducing kind of heat treatment process in which steel is heated to a temperature above the critical point and held at that temperature for a definite time and then quenched rapidly in water, oil or molten salt bath. It is some time said as rapid quenching also. Steel is hardened by heating 20-30°C above the upper critical point for hypo eutectoid steel and 20-30°C above the lower critical point for hyper eutectoid steel and held at this temperature for some time and then quenched in water or oil or molten salt bath. Fig 8.7 shows the heating temperature ranges for hardening process of both hypo and hyper carbon steel. Fig. 8.10 (a) shows the structure obtained on water quenching on hardening of medium carbon steel. Fig. 8.10 (b) shows the structure obtained on oil quenching on hardening of medium carbon steel. Fig. 8.10 (c) shows the structure obtained on water quenching on hardening of medium carbon steel and followed by tempering.



(a) **(b)** **(c)**

Fig. 8.10 Structure of hardened carbon steel

Metal is heated up to austenite formation and is followed by fast and continuous cooling of austenite to temperature 205° to 315°C or even lower than that. Due to such rapid cooling, austenitic structure changes to new structure known as martensite. It is evident that faster the rate of cooling harder will be the metal due to formation of more martensitic structure. Martensite has a tetragonal crystal structure. Hardness of martensite varies from 500 to 1000 BHN depending upon the carbon content and fineness of the structure. Martensite is a body centered phase produced by entrapping carbon on decomposition of austenite when cooled rapidly. It is the main constituent of hardened steel. It is magnetic and is made of a needle like fibrous mass. It has carbon content up to 2%. It is extremely hard and brittle. The decomposition of austenite below 320°C starts the formation of martensite.

Sudden cooling of tool steel provides thermal stresses due to uneven cooling. It provides unequal specific volume of austenite and its decomposition product. The structural transformations are progressing at different rates in outer layers and central portion of the article. When martensitic transformation takes place in the central portion of the article, due to tension stress produces cracks. The harness depends upon essentially on the cooling rate. The effect of cooling on austenite transformation is given in Fig. 8.11.

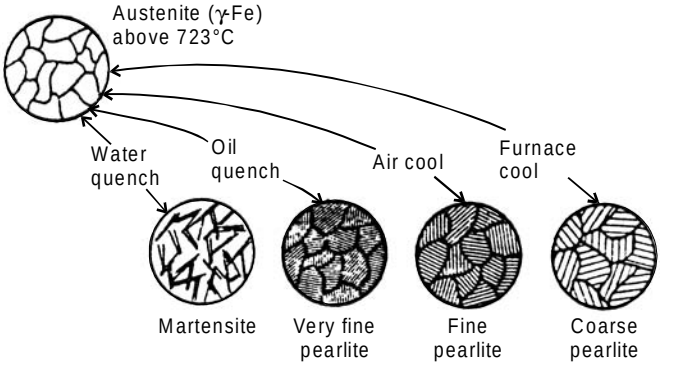


Fig. 8.11 Effects of coooling of austenite transformation

8.13 TTT CURVE

The hardness depends upon the structure of materials. The different structure through transformation can be obtained using different cooling rates. The effects of cooling of austenite (steel above 723°C) transformation are depicted in Fig. 8.11. It can be nicely represented in a temperature, time and transformation (TTT) curve. It is also known as C or S or Bain's curve. Fig 8.12 shows TTT diagram for hypo eutectoid steel.

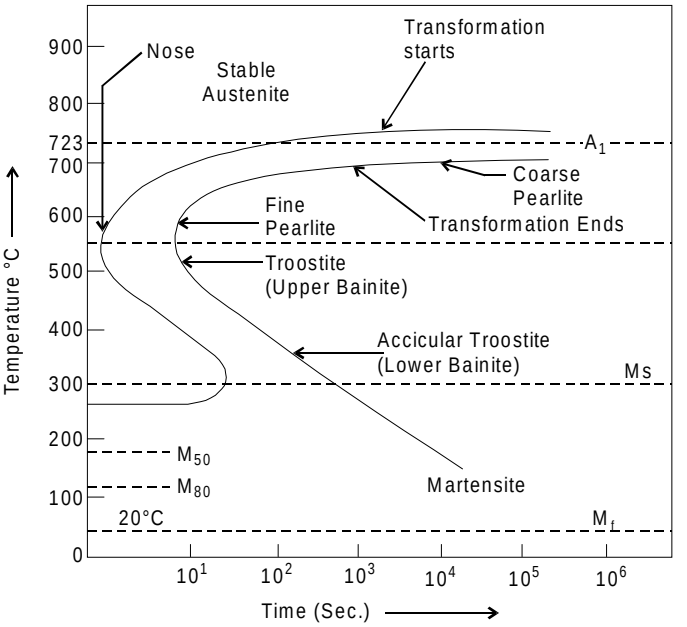


Fig. 8.12 TTT diagram for hypo eutectoid steel

Fig. 8.13 shows a series of cooling curves which result from different rates of cooling when superimposed on TTT curve. These curves reveal the decomposition of stable austenite existing above critical temperature in various forms during cooling depending upon the cooling rate. The transformation of austenite starts during suitable cooling. The minimum cooling rate required to produce martensite in given steel is determined by the position of the nose of the S curve. The cooling rate required to avoid the nose of the S curve is called the critical cool. Any other cooling rate, faster than to that of the nose of S curve will cause complete transformation of austenite to martensite.

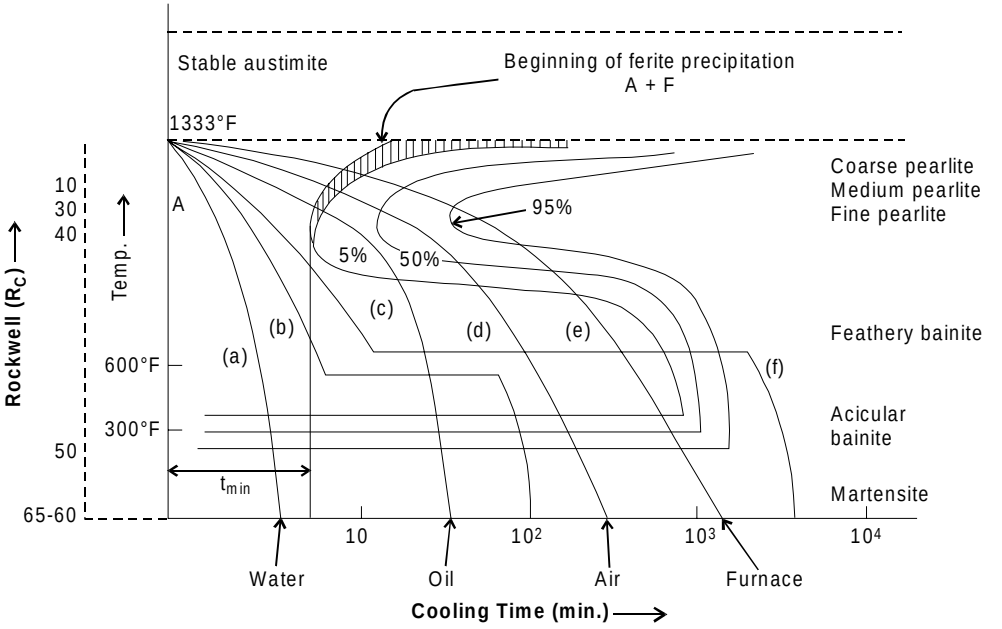


Fig. 8.13 Series of different cooling rates curves in TTT diagram

Assume a cooling rate 'a' achieved in water, this curve does not cut the nose of TTT curve, and the pearlite transformation does not take place. However the resulting structure at room temperature is martensite. Cooling curve 'c' reflects that the cooling rate is slower than water and is in oil still lesser than the critical cooling rate, the curve 'c' will result in the micro structure composed of martensite. Curve 'd' and curve 'e' corresponds to the rate of cooling during normalizing and annealing. The parts of austenite transform to fine and coarse pearlite. The intermediate cooling rate curves 'f' and 'b' higher than critical cooling rate results in the structure between pearlite and martensite known as feathery bannite and acicular (needles) bannite. Intermediate cooling rate is achieved by quenching or dipping the austenite at two hot oil baths maintained at different temperature such as in case of austempering (f curve) and mar tempering (b curve). Those special cooling rate will form coarse and fine bainite structure according the level of temperature of quenching.

Transformation of austenite to pearlite depends upon the temperature, time and transformation curve. It relates the transformation of austenite to the time and temperature conditions to which it is subjected. As metal is heated above the critical point austenite will form in the structure of metal if it is cooled slowly with respect to time. The structure wil1 change to coarse pearlite and cementite placeless in a ferrite matrix due to transformation

of temperature and hence nuclei thus formed grow rapidly. Such as coarse laminar pearlite is relatively soft and is not very ductile. After this, if slightly faster cooling than above slow cooling is applied to austenite; coarse bainite structure will be formed.

8.14 TEMPERING

If high carbon steel is quenched for hardening in a bath, it becomes extra hard, extra brittle and has unequal distribution internal stresses and strain and hence unequal harness and toughness in structure. These extra hardness, brittleness and unwanted induced stress and strain in hardened metal reduce the usability the metal. Therefore, these undesired needs must be reduced for by reheating and cooling at constant bath temperature. In tempering, steel after hardening, is reheated to a temperature below the lower critical temperature and then followed by a desired rate of cooling. Reheating the of hardened steel is done above critical temperature when the structure is purely of austenite and then quenching it in a molten salt path having temperature in the range of 150-500°C. This is done to avoid transformation to ferrite and pearlite and is held quenching temperature for a time sufficient to give complete formation to an intermediate structure referred to as bainite then cooled to room temperature. The temperature should not be held less than 4 to 5 minutes for each millimeters of the section. After tempering structure is changed into secondary structure like martensite, troostite, sorbite and spheroidised. Fig. 8.14 shows different tempered states of martensite, troosite, sorbite and spherodite. Depending upon the temperature of reheat, the tempering process is generally classified in to three main categories. Which are discussed as under.

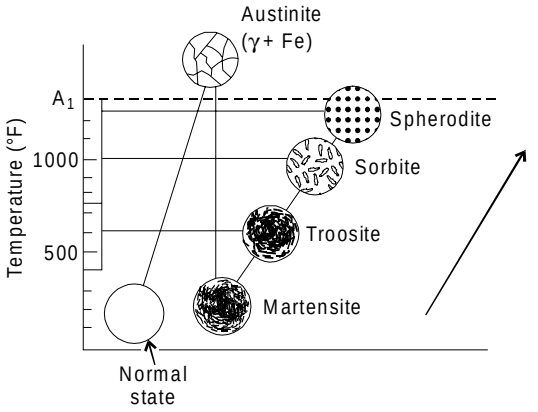


Fig. 8.14 Structures of tempered states of martensite, troosite, sorbite and spherodite

8.14.1 Low Temperature Tempering

Hardened steel parts requiring tempering are heated up to 200°C and then quenched in oil. Tempering is used to retain hard micro-structure of martensite which increases brittleness. Fig 8.15a represents the microstructure of martensite.

8.14.2 Medium Temperature Tempering

Hardened steel parts requiring tempering are heated in the temperature range of 200-350°C. This process gives troosite structure. Troosite structure is another constituent of steel obtained by quenching tempering martensite. It is composed of the cementite phase in a ferrite matrix that cannot be resolved by light microscope. It is less hard and brittle than martensite. It is

also produced by cooling the metal slowly until transformation begins and then cooling rapidly to prevent its completion. It has a dark appearance on etching. It is weaker than martensite. Fig 8.15b represents the microstructure of troosite

8.14.3 High Temperature Tempring

Hardened steel parts requiring tempering are heated in the temperature range of 350-550°C. This process gives sorbite structure. Sorbite structure is produced by the, transformation of tempered martensite. It is produced when steel is heated at a fairly rapid rate from the temperature of the solid solution to normal room temperature. It has good strength and is practically pearlite. Its properties are intermediate between those of pearlite and troosite. Parts requiring tempering are heated in the temperature range of 550-750°C. This process gives spheriodite structure. Fig 8.15(c) represents the microstructure of sorbite. However there are other special kinds of tempering also which are discussed as under.

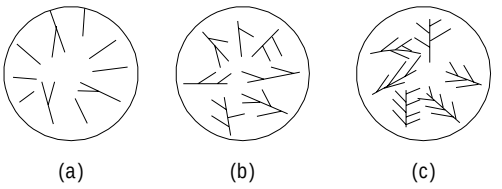


Fig. 8.15 Structures obtained tempering of hardened steel

8.14.4 Aus-Tempering

It is a special type of tempering process in which and steel is heated above the transformation range then suddenly quenched in a molten salt bath at a temperature 200 to 450°C. The piece is held at that temperature until the and outside temperature are equalized. The part is then reheated and cooled at moderate rate. Aus-tempering produces fine bainite structure in steel but with minimum distortion and residual stresses. Fig. 8.16 shows the process of aus-tempering for medium C-steel. Aus-tempering is mainly used tempering for aircraft engine parts.

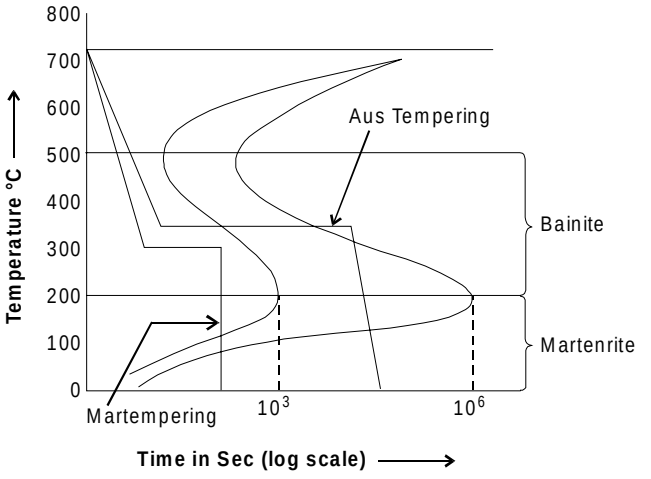


Fig. 8.16 Aus tempering and mar tempering process

Advantages of Aus-Tempering

1. Quenching cracks are avoided.
2. Distortion and warping are avoided.
3. A more uniform microstructure is obtained.
4. Mechanical properties of bainite are superior to conventional hardening microstructure.

Limitations of Aus-Tempering

1. The process is very costly.
2. The process is time consuming.

8.14.5 Mar Tempering

It is a type of tempering process in which and its base alloys are heated above the transformation range then suddenly quenched in a molten salt bath at a temperature 80 to 300°C. The piece is held at that temperature until the and outside temperature are equalized. The part is then reheated and cooled at moderate rate. Mar-tempering produces martensite in steel but with minimum distortion and residual stresses. Fig. 8.16 shows the mar tempering process for medium C-steel and its micro structures of given stages. Cold chisels are hardened at the cutting edge and followed by tempering. Because these processes increase the hardness of chisel and increase the cutting ability.

8.15 CASE HARDENING

Some times special characteristic are required in metal such as hard outer surface and soft, tough and more strength oriented core or inner structure of metal. This can be obtained by casehardening process. It is the process of carburization i.e. saturating the surface layer of steel with carbon or some other substance by which outer case of the object is hardened where as the core remains soft. It is applied to very low carbon steel. It is performed for obtaining hard and wear resistance on surface of metal and higher mechanical properties with higher fatigue, strength and toughness in the core. The following are the case hardening process.

(1) Carburizing
(2) Nitriding.
(3) Cyaniding.
(4) Induction hardening.
(5) Flame hardening

These processes are discussed as under.

8.15.1 Carburizing

Carburizing can be of three types

1. Pack carburizing
2. Liquid carburizing and
3. Gas carburizing

The above carburizing processes are discussed as under.

8.15.1.1 Pack Carburizing

Metals to be carburized such as low carbon steel is placed in cast iron or steel boxes containing a rich material in carbon like charcoal, crushed bones, potassium Ferro-cyanide or charred leather. Such boxes are made of heat resisting steel which are then closed and sealed with clay. Long parts to be carburized are kept vertical in -boxes. The boxes are heated to a temperature 900°C to 950°C according to type of steel for absorbing carbon on the outer surface. The carbon enters the on the metal to form a solid solution with iron and converts the outer surface into high carbon steel. Consequently pack hardened steel pieces have carbon content up to 0.85% in their outer case. After this treatment, the carburized parts are cooled in boxes. Only plane carbon steel is carburized in this process for hardening the outer skin and refining the structure of the core to make it soft and tough. Small gears are case hardened by this process for which they are enclosed in the cast iron or steel box containing a material rich in carbon, such as small piece of charcoal and then heat to a temperature slightly above the critical range. Depth of hardness from 0.8-1.6 mm is attained in three to four hours. The gears are then allowed to cool slowly with-in the box and then removed. The second stage consists of reheating the gears (so obtained) to about 900°C and then quenched in oil so that its structure is refined, brittleness removed and the core becomes soft and tough. The metal is then reheated to about 700°C and quenched in water so that outer surface of gear, which had been rendered soft during the preceding operation, is again hardened.

8.15.1.2 Liquid Carburizing

Liquid carburizing is carried out in a container filled with a molten salt, such as sodium cyanide. This bath is heated by electrical immersion elements or by a gas burner and stirring is done to ensure uniform temperature. This process gives a thin hardened layer up to 0.08 mm thickness. Parts which are to be case-hardened are dipped into liquid bath solution containing calcium cyanide and polymerized hydro-cyanide acid or sodium or potassium cyanide along-with some salt. Bath temperature is kept from 815°C to 900°C. The furnace is usually carbon steel case pot which may be by fired by oil, gas or electrically. If only selected portions of the components are to be carburized, then the remaining portions are covered by copper plating. There are some advantages of the liquid bath carburizing which are given as under.

Advantages

1. Greater depth of penetration possible in this process.
2. Selective carburizing is possible if needed.
3. Uniform heating will occur in this process.
4. Little deformation or distortion of articles occur in this process.
5. Ease of carburizing for a wider range of products.
6. It is time saving process.
7. Parts leave the bath with a clean and bright finish.
8. There is no scale in this process as occur in pack hardening.

8.15.1.3 Gas Carburising

In gas carburizing method, the parts to be gas carburized are surrounded by a hydrocarbon gas in the furnace. The common carburizing gases are methane, ethane, propane, butane and carbon monoxide are used in this process. Carbon containing gas such as carbon monoxide (CO), methane (CH_4), ethane (C_2H_6) or town gas is introduced in the furnace where low

carbon steel is placed. The furnace is either gas fired or electrically heated. Average gas carburizing temperature usually varies from 870° to 950°C. Thickness of case hardened portion up to 11 mm can be easily obtained in 6 hours. The carburized parts can heat treated after carburizing. Steel components are quenched in oil after carburizing and then heated again to form fine grain sized austenite and then quenched in water to form martensite in surface layers. This gives maximum toughness of the core and hardness of the surface of product.

8.15.2 Cyaniding

Cyanide may also be used to case harden the steel. It is used to give a very thin but hard outer case. Cyaniding is a case hardening process in which both C and N_2 in form of cyaniding salt are added to surface of low and medium carbon steel. Sodium cyanide or potassium cyanide may be used as the hardening medium. It is a process of superficial case hardening which combines the absorption of carbon and nitrogen to obtain surface hardness. The components to be case hardened are immersed in a bath having fused sodium cyanide salts kept at 800-850°C. The component is then quenched in bath or water. This method is very much effective for increasing the fatigue limit of medium and small sized parts such as gears, spindle, shaft etc. Cyanide hardening has some advantages and disadvantage over carburizing and nitriding method. Cyaniding process gives bright finishing on the product. In it, distortion can be easily avoided and fatigue limit can be increased. Decarburizing can be reduced and time taken to complete the process is less. But the main disadvantage of this process is that it is costly and highly toxic process in comparison to other process of case hardening. There are some common applications of cyaniding process which are given as under.

Application

Cyaniding is generally applied to the low carbon steel parts of automobiles (sleeves, brake cam, speed box gears, drive worm screws, oil pump gears etc), motor cycle parts (gears, shaft, pins etc.) and agriculture machinery.

8.15.3 Nitriding

Nitriding is a special case hardening process of saturating the surface of steel with nitrogen by holding it for prolonged period generally in electric furnace at temperature from 480°C to 650°C in atmosphere of Ammonia gas (NH3). The nitrogen from the ammonia gas enters into on the surface of the steel and forms nitrides and that impart extreme hardness to surface of the metal. Nitriding is a case hardening process in which nitrogen instead of carbon is added to the outer skin of the steel. This process is used for those alloys which are susceptible to the formation a chemical nitrides. The article to be nitride is placed in a container (made of high nickel chromium steel). Container is having inlet and outlet tubes through which ammonia gas is circulated. Ammonia gas is used as the nitrogen producing material. The alloy steel containing Cr, Ni, Al, Mo, V and Nitre-alloy are widely used for this process. Plain carbon steels are seldom nitirided. There are some common applications of this process which are given as under.

Application

Many automobile, diesel engines parts, pumps, shafts, gears, clutches, etc. are treated with the nitriding process. This process is used for the parts which require high wear resistance at elevated temperatures such as automobile and air plane valve's and valve parts, piston

pins, crankshafts, cylinder liners etc. It is also used in ball and roller bearing parts die casting dies, wire drawing dies etc.

8.15.4 Flame Hardening

It consists of moving an oxyacetylene flame, over the part where hardening is required. Immediately after this, the heated portion is quenched by means of water spray or air passing over it. Temperature attained by the surface is controlled and the rate of cooling is controlled by selecting a suitable medium. Flame hardening is suitable for large sized articles where only some portions of the surface requiring hardening and hence there is no need to heat the whole article in the furnace. Metal is heated by means of oxy-acetylene flame for a sufficient time unto hardening range and than quenched by spray of water on it. The hardened depth can be easily controlled by adjusting and regulating the heating time, temperature, flame and water spray. The main advantages of the process is that a portion of metal can be hardened by this process, leaving rest surface unaffected by confining the flame at relevant part only where hardening is required. This process is best suited to smal1 numbers of jobs which requiring short heating time. This method is highly suitable for stationary type of larger and bulky jobs.

8.15.5 Induction Hardening

Induction hardening is accomplished by placing the part in a high frequency alternating magnetic field. It differs from surface hardening in the way that hardness of surface is not due to the increase in carbon content but due to rapid heating followed by controlled quenching. In this process, a high frequency current is introduced in the metal surface and its temperature is raised up to hardening range. As this temperature is attained, the current supply is cut off instantaneously water is sprayed on the surface. Heat is generated by the rapid reversals of polarity. The primary current is carried by a water cooled copper tube and is induced into the surface layers of the work piece. Thin walled sections require high frequencies and thicker sections must require low frequencies for adequate penetration of the electrical energy. The heating effect is due to induced eddy currents and hysteresis losses in the surface material. Some portion of the metal part is heated above the hardening temperature and is then quenched to obtain martensite on the metal surface. There are some advantages of this process which are given as under.

Advantages

Induction hardening is comparatively quicker. A minimum distortion or oxidation is encountered because of the short cycle time. The operation is very fast and comparatively large parts can be processed in a minimum time. There are some applications of this process which are given as under.

Application

Induction hardening is widely used for hardening surfaces of crankshafts, cam shafts, gear automobile components, spline shafts, spindles, brake drums etc. It is also used for producing hard surfaces on cam, axles, shafts and gears.

8.15.6 Difference between Flame and Induction Hardening

Flame hardening and induction hardening methods have the same purpose of obtaining hard and wear surface whilst the core remains soft. The main difference between them is in the manner or the mode of heating.

In the induction hardening high frequency current of about 1000 to 10000 cycles per is passed through a copper inductor block which acts as a primary coil of the transformer. Heating by high frequency current is accomplished by the thermal effect of the current induced in the article being heated in this process. This way 750°C to 800°C temperature is obtained in the metal. Now, the heated surface is quenched by the water. In the flame hardening process, the metal surface is heated by means of oxy-acetylene flame. Heating is carried for sufficient time so as to raise the temperature of the portion of the surface of the specimen above the critical temperature. Then surface is cooled rapidly by spray of water.

Flame hardening method is cheaper as initial investment in this process is less in comparison to induction hardening method. However, same equipments can be used for all sizes of specimen in induction hardening process.

In induction hardening, the hardness depth is controlled very accurately by using different frequencies and a method is very clean and quick in comparison of flame hardening method.

Induction hardening method is generally used for crank shaft shafts, gears, pinions and a wide range of automobile and tractor components. Flame hardening method is generally used for local hardening of components such as hardening of gear wheel teeth only.

8.16 COMPARISON BETWEEN FULL HARDENING AND CASE HARDENING

The comparison between full hardening and case hardening is under in Table 8.2.

Table 8.2 Comparison between Full Hardening and Case Hardening

S.No.	Full Hardening	Case Hardening
1	It is process carried out on steel parts to resist wear or abrasion and in case of cutting tools to improve their cutting ability.	The main objective of case- hardening of steel parts is to have a hard surface and tough core. The various methods are, carburizing, cyaniding, nitriding, flame hardening and induction hardening.
2	In this process, the structure formed of materials and whole of the part is effected.	In this process, the only outer surface (up to some depth) is saturated by carbon, nitrogen or both. Where core is not affected (remains tough).
3	Its main purpose is to resist wear and increase the cutting ability.	Its main purpose is get outer surface hard where inner core is kept tough. It is used to obtain close tolerances on machine parts, higher fatigue limit and high mechanical properties in core of the metal part.
4	Hardening is always followed by tempering to increase its usefulness.	Case hardening is not always followed by tempering.
5	In hardening the metals are heated above critical temperature and then cooled rapidly.	In case hardening, the metals are heated obut it not necessary to cool them rapidly. always.
6	It is a cheap and fast process.	It is costly and time consuming process.

8.17 HEAT TREATMENT OF TOOL STEEL

First of a1l, the purpose or functional requirements of the tool to be used should be understood clearly. Accordingly the heat-treatment will be carried on the tool to obtain the desired qua1ities in the tool steel to meet the needed objective. For example a cutting tool requires particularly sufficient strength, high hardness and high wear-resistance. Therefore, it is initially shaped by forging operation which should be carried out at temperature 850°- 950°C with the help of hammers. Next normalizing is to be performed on it to relieve the stresses and strains developed during forging and to have a uniform grain structure. Next the tool steel is hardened by heating followed by sudden or rapid cooling depending upon the carbon percentage in tool steel. The various heating ranges of different tool steels are as follows

C% in tool steel	Heating Range
0.7- 0.8%	780-850°C
0.8- 0.95%	765-790°C
0.95-1.10%	750-775°C
Above 1.10 %	740-760°C

The tool steel is heated to this temperature range and kept at that temperature for sufficient time to achieve uniform structure inside the metal. Then it is quenched by immersing it into a bath of fresh water (rapid cooling). For securing more homogenous cooling and reduce danger of cracking, brine solution (10% brine or caustic soda solution) may be used. After hardening, tempering is performed to remove extra hardness and brittleness induced during hardening. This is performed by reheating the hardened tool steel up to 150-300°C once again and same is cooled in oils to reduced internal stresses. Tempering is carried over to tool steel for the purpose of increasing its usefulness and to provide good results in its performance. The important point is to note that drills and milling cutters should be hardened through out. But certain tools like screw taps, screw dies, lathe, planer and shaping tools are not hardened throughout the surface of the cutting tools.

8.18 HEAT TREATMENT OF HIGH SPEED STEEL

First the HSS tool is heated to about 850°C and kept at this temperature for 4 to 5 hours. This is done to dissolve all the carbides or homogenization of WC, VC and Cr_4C_3. After it, tool is heated to 1200°C for 1-4 minutes. The purpose of heating to high temperature is that more the substance is cooled from high temperature to lower temperature difference, the more will be the hardness. Tool is not kept at such temperature for sufficient longer time. After this, it is quenched in salt bath to 650°C and kept at this temperature for 10-20 minutes. Direct quenching to room temperature is dangerous. Then the tool is oil quenched. For increasing the life of HSS tool, surface treatment processes are also done like, liquid cyaniding, gas cyaniding and solid or dry cyaniding.

8.19 QUESTIONS

1. Why are the Time-Temperature-Transformation (TTT) diagrams constructed?
2. How do you classify the different heat treatment processes?
3. What are the objectives of annealing?
4. Explain the various methods of annealing?
5. Explain various hardening methods?

6. Write short notes on :
   (*a*) Normalizing
   (*b*) Tempering
   (*c*) Mar-tempering
   (*d*) Aus-tempering
   (*e*) Case hardening
   (*f*) Flame hardening
7. Discuss tempering process in detail?
8. Discuss various types of surface hardening or case hardening processes?
9. Explain the following case hardening processes:
   (*a*) Cyaniding
   (*b*) Nitriding
   (*c*) Induction Hardening
   (*d*) Types of carburizing
10. Write short notes on :
   (*a*) Sub zero treatment of steels
   (*b*) Age Hardening.
11. Explain various heat treatment defects with causes and remedies.

9
CHAPTER

CARPENTRY

9.1 INTRODUCTION

Wood obtained from tree is the chief product of forest. It has been universally acceptable as raw material for manufacturing wooden products or appliances. From the pre-historic times, wood has been utilized an important source of getting heat by firing it. It has been utilized as an mazor construction material for making shelter for the basic need of human being. As the civilization advanced, it gained tremendous importance as special material for boat-building, for piling to support docks and railroad tracks. But in modern times, with the advance of wood chemistry, the uses of wood have recognized its importance in manufacturing cheap useful products used in day today life such as paper, furniture, textiles, plastics and hundreds of chemicals and extractives. The wooden products as plywood have superseded in some products in comparison metallic and ceramic materials. Compressed wood has also replaced some metals for gears and die casts. In war-time, in Europe, wood has been used as a source of wood gas for propelling automobiles. Similarly clothing has-been made from wood cotton and wood wool. The useful work on wood is being generally carried out in a most common shop known as carpentry shop. The work performed in carpentry shops comprises of cutting, shaping and fastening wood and other materials together to produce the products of woods. Therefore, carpentry shop deals with the timber, various types of tools and the art of joinery. In wood, there are two types of cells namely radiating outward from the center of wood cross-section and running parallel to the length of wood. Trees are generally classified into exogenous and endogenous types according to manner of growth.

Exogenous types are also known as outward growing trees which produce timber for commercial use. They grow outward and the additional growth which occurs each year takes place on the outside of the trunk just underneath its bark, while the innermost timber continues to mature. Each time the growth cycle is completed the tree gains one more growth ring or annual ring. In counting these rings, the age of a tree can be determined, as each ring represents one year of growth.

Endogenous trees are also known as inward growing. They grow inwards i.e., every fresh layer of sapwood is added inside instead of outside. Cane, bamboo and coconut are examples of such endogenous trees.

Timber is a common name imparted to wood suitable for engineering, construction and building purposes. Timber is obtained from trees by cutting the main body of tree in the suitable sizes after the full growth of tree. The timber structure is consisting of annual rings,

heartwood, sapwood, pith, cambium layer, bast, medullary rays and bark. Commercial timbers are commonly classified into hardwoods and softwoods. Hardwoods comprises of oak and beech that have a broad leaf. Whereas softwoods include pine and spruce which have narrow needle like leaf.

This chapter presents the various kinds of material, tools and equipments used in carpentry shop along with their properties and uses.

9.2 HARD AND SOFT WOOD

Hard wood is generally obtained from broad leaves or deciduous trees where as the softwood from trees having needle shaped yes or conifers. The major differences between hard wood and soft wood are given as under.

Table 9.1 Difference between Hard Wood and Soft Wood

S.No.	Hard Wood	Soft Wood
1	It is dark in color	Its color is light
2	It is heavy in weight.	It is light in weight
3	Hard woods are harder and denser.	Soft woods are comparatively lighter
4	It has less resin content	Few softwoods are resinous.
5	It does not split quickly	It gets splitted quickly
6	It is difficult to work.	It is easy to work.
7	It's annual rings are close and often indistinct	Its annual rings are well spaced and quit distinct
8	It is slow growing.	It is fast growing.
9	It has good tensile and shear resistance.	It has good tensile resistance but is weak across the fibers.
10	It does not catch fire very soon	It catches fire very soon.

9.3 TYPES OF COMMON TIMBERS, THEIR QUALITIES AND USES

The common types of well recognized timbers available in India are Shisham, Sal, Teak, Deodar, Mango, Mahogany, Kail, Chid, Babul, Fir wood, Walnut and Haldu,. Out of these, Deodar, Chid, Kail, Fir wood and Haldu fall in the categories of softwoods and Shisham, Sal, Teak, Kiker, Mango, Walnut fall in the categories of hardwoods. Some of the other foreign timbers commonly used in India are Ash, Burma, Hickory, Oak and Pine.

1 **Shisham** is dark brown in color and it possesses golden and dark brow stripes. It is very hard to work and generally wears or blunts the sharp edge of cutting tool very soon. It is available in India in Himalayan range at heights from 1000-1500 meters and in deep forests. It is recognized as highly strong and durable wood and it is mainly used for making good variety of furniture, tool handles, beds, cabinets, bridge piles, plywood etc.

2 **Sal** exists in rose brown color which slowly turns into dark brown. This wood is commonly available in India in Himalayas, M.P and U.P. It is free from attack of white ants insects and it is very difficult to work. It has poor finish and therefore

is not used for decorative furniture. It finds tremendous applications in making doors, windows, cots, wooden handles, furniture and railway sleepers etc.

3 **Teak wood** is hard, very costly and it possesses wide applications. It is available in golden yellow or dark brown color. Special stripes on it add to its beauty. In India, it is found in M.P. It is very strong, durable and it maintains good polish. It is mainly used for making good quality furniture, plywood, ships etc.

4 **Deodar** is white in color when soft. But when it is hard, its color turns toward light yellow. It is strong and durable. It provides fragrance when smelled. It is not easily attacked by insects as it has some quantity of oil in it. It is commonly available in Himalayas at a height from 1500 to 3000 meters. It is used for manufacturing of doors, furniture, patterns, railway sleepers etc.

5 **Mango** is brown in color and it can be easily shaped in various products. It is widely used in India as a cheap wood for making doors, packing cases, toys and inferior furniture.

6 **Mahogany** is reddish brown in color which is highly durable when dry. It also contains some oil in it that prevents it from the attack of insects. It is commonly utilized for manufacturing cabinet, fine furniture, pattern making work etc.

7 **Kail** wood possesses too many knots in it. This wood is commonly found in Himalayas of India. It yields a close grained, moderately hard and durable wood which can be easily painted. It is commonly utilized for making cheap furniture, wooden doors, packing case etc.

8 **Chid** is also known as Chir. Its color is dark brown when is soft, but it is reddish brown when hard. It has stripes of dark brown color. It has oily smell and is used for interior work in the house.

9 **Babul** is close grained tough and pale red colored wood and is used for making tool handles etc.

10 **Fir wood** is light brown in color when soft but harder variety is found in dark brown color. It can be easily attacked by insects. It is commonly utilized for making drawers, packing cases, doors etc.

11 **Walnut** is a good variety of wood which resists the attack of white ants. It can be polished easily in a better way. This wood is generally used for making musical instruments, furniture, cabinet work, decoration work etc.

12 **Haldu** is white in color at the time of cutting, but once cut, its color becomes yellow. It can be dried and polished satisfactorily. It is widely used for making small objects such as stool, picture frames, trays, cabinet etc.

9.4 FELLING, CONVERSION AND SEASONING OF WOOD

Cutting of living or standing trees to obtain timber is called felling of trees. Trees are cut at appropriate time. The best time for sawing the tree is immediately after the tree has achieved its full growth or maturity age so that the maximum quantity and best quality of wood can be obtained. If an immature tree is cut, it will carry a lot of sapwood which may not be much useful for the carpentry work. Contrary to this, if the tree is allowed to stand for long after attaining the maturity the most valuable part of timber will be subjected to decay. Therefore enough care must be taken to see that felling is accomplished only at the appropriate time.

The proper time of cutting of a tree depends largely on its age and season of the year. Cutting of trees for getting wood for use is done generally in mid-summer or mid-winter because the sap of the tree is at rest during this period and therefore, the chances of any decay of useful wood are minimized. The time taken for a tree to mature depends whether it is softwood or hardwood. The softwood tree will mature after 80 to 100 years whereas hardwood will take more time between 130 and 200 years for getting mature. After cutting the trees from bottom, the branches are removed from it and form of log is obtained. The process of sawing wooden logs into useful sizes and shapes (boards, planks squares and other planes section and sizes etc.) for market or commercial requirements is known as conversion. Conversion is carried over prior to seasoning by two methods namely plain, through, through sawn process and quarter and rift sawn process. Plain sections of wood may likely to warp and hence cannot be used for quality work. Quarter sawing almost eliminates the chances of warping. Quarter sawn sections are used as quality wood in cabinet making, decoration and framework. Plantation of new trees is also essential and that should be carried out form time to time.

Conversion means sawing of timber logs into different commercial sizes. A notable feature in conversion is to provide an adequate allowance for shrinkage that takes place during seasoning of sawn or converted wood. The shrinkage of wood usually varies between 3.2 mm to 6.4 mm, according to the type of wood and its time of cutting. The three methods of conversion commonly adopted are discussed as under.

The first method is called as flat or ordinary cutting which is the simplest procedure of sawing but the cut sections are likely to warp. Therefore, the wood cut through this procedure cannot be called as quality work. In this method, the timber log is cut into a number of boards by taking various parallel saw cuts into the suitable forms.

The second method is known as tangential cutting in which cutting takes place in such a way that the widths of the boards are tangential to the annual rings. The timber cut by this method is seasoned quickly and cutting wastage is also less but it may warp like flat sawn wood.

The third procedure is known as quarter or radial sawing in which the timber logs are sawn so that the width of the sawn boards falls along the medulary rays which mean they run across the section of the log. The normal defect of warping is almost eliminated by this procedure of sawing and the timber is very suitable for all sorts of wood work involving cabinet-making, decoration and framework. Trees are converted into the following useful marketable forms such as posts (square pieces of timber 175-300 mm wide or round pieces of 175-300 mm in diameter), deals (225 mm wide and about 100 mm thick parallel side pieces), planks (50 to 100 mm thick, 275-300 mm wide and 3 to 7 meters long) and boards or battens (25 to 50 mm thick and 125 to 175 mm wide). Sizes of timber (Kail, Deodar etc.) available in the market for building construction purposes are $10' \times 10'' \times 5''$ or $12' \times 10'' \times 5''$ or $10' \times 8'' \times 5''$ or $10' \times 8'' \times 4''$ etc.

Seasoning of wood is the reduction of the moisture or sap content of it to the point where, under normal conditions of use, no further drying out will take place. The main objective of seasoning is to reduce the unwanted amount of moisture from the timber. As the moisture contained in the cell walls evaporates, shrinkage of the timber takes place which is greatest along the growth rings. Certain other defects such as shaking and warping may develop during seasoning. Therefore for these reasons green or unseasoned timber should not used for any work but for rough work. Once the timber is seasoned before use, it will not shrink, twist or swell during its further use. Need for seasoning of timber before its use is

necessary in order to achieve the required moisture content, to reduce fungi decay, to minimize attack of insects, to increase strength of wood and for reduction of wood warpage Seasoning is classified into two categories namely natural seasoning and artificial seasoning. Natural seasoning is carried out generally in air, or in water or in smoke. Air seasoning is the oldest method of drying timber and it depends entirely upon the free flow of air around the wood to evaporate moisture. A timber stack in a shade for air seasoning is shown in Fig. 9.1.

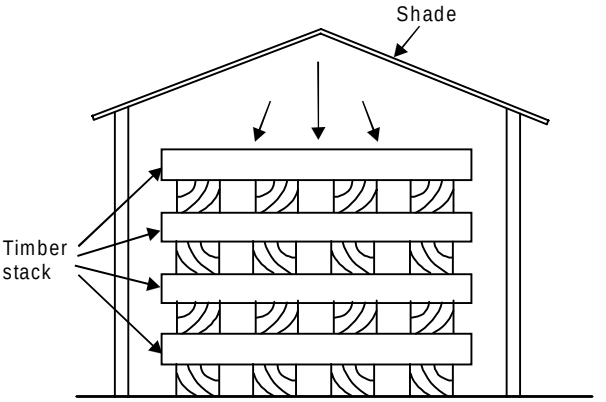


Fig. 9.1 Timber stack in a shade for air seasoning

In water seasoning, the timber balks are immersed in water for 15-20 days. During period, the flowing water drives away the sap pf wood it. Timber is then taken out and dried in open air for about a month. Water seasoning takes less time than air seasoning, but the strength of wood is reduced. However by water seasoning, the timber is less liable to warp, crack and distort. This method of seasoning is highly suitable for seasoning green wood full of sap. This seasoning process renders timber less liable to rot decay. In smoke seasoning, the wood is dried by using the smoke of rough burning timber and waste leaves. The smoke seasoning is used for woods in boats. Artificial seasoning is controlled by application of both heat and humidity which enables to reduce the moisture content quickly and accurately. After artificial seasoning the wood becomes harder, whereas in natural seasoning the wood becomes soft. Kiln seasoning is an important type of artificial seasoning as shown in Fig. 9.2 in which the timber is seasoned by the use of a forced draught of warm air in which brings about a rapid reduction in moisture content.

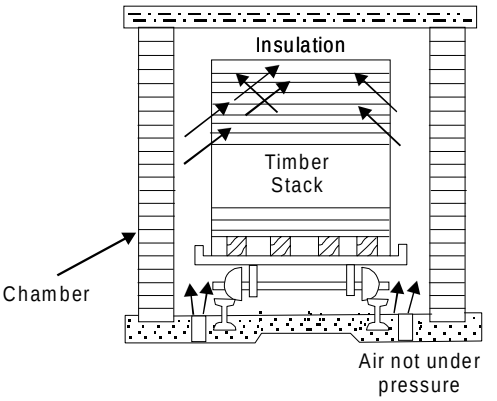


Fig. 9.2 Timber stack in kiln seasoning

9.5 DEFECTS IN TIMBER

Defects in timber may be broadly classified into three major categories

1 Due to abnormal growth of trees

2 Due to conversion or seasoning and

3 Due to fungi and insects.

The defects in each category are described as under.

9.5.1 Defects Due to Abnormal Growth of Trees

Defects due to abnormal growth of trees are natural in nature and they are knots, stakes, twisted fiber and rind galls.

Knots are too much frequent in many trees. They break the continuity of fiber and weaken the timber. These defects may of dead or live kind. Fig. 9.3 shows a knot defect. A dead knot will come out of the wooden piece leaving a knot hole. It is produced when a branch is broken off before the tree has finished growing. A live knot occurs when a branch separates from the tree after felling of the tree. Live knot will not become loose and fall out of its position but may tend to crack. This provides inlets for any fungi to attack the wood. If these knots are not too large and not too near the edge of the plank, they will not present a great problem however dead knots in timber makes the wood unsuitable for structural use.

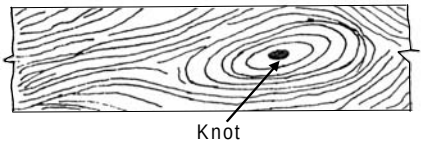


Fig. 9.3 Knot defect in timber

Shakes in timber are splits in the grain and often arise as a result of uneven seasoning. They may be of radial, heart, star, cup and upset kind. An upset or rupture is a shake in which the fracture occurs across the grain. This is thought to be caused by violet jarring of the timber during felling and is often found in mahogany.

Sometimes, the fibers of a tree may get twisted due to wind action in branches. This defect is known as **twisted fibers** defect in timber. The fibers of wood have different inclinations with its axis. They are no more parallel to the axis of the wood. Twisted fibers in timber offer difficulty in working and a smooth surface cannot be obtained.

Rind gall is the defects due to abnormal growth of trees. It is the wound created on the tree while a branch breaks and parts off or gets cut. Decay may occur at that point.

9.5.2 Defects Due to Conversion and Seasoning

Defects due to conversion and seasoning of timber involve shakes, warping, bowing, twist, diamonding, casehardening and honey combing. Some of such important defects are discussed as under.

Warping is a kind of variation from a true or plain surface and may include a one or combination of cup, bow, crook and twist. Warping board which is tangentially sawn may invariably warp. This takes the form of a hollowing or cupping across the face of the board and when wide flat boards are required this will act as a serious drawback. Wind or twist defect occurs when thin boards are cut from a log having curved longitudinal grain. This tendency is for the board distort spirally.

Diamonding in timber is the tendency of square cut pieces to become diamond shaped when cut from certain areas of the log. This happens when the piece has been cut with growth rings running diagonally, causing the unequal shrinkage between summer and spring growth to pull it out of shape.

9.5.3 Defects due to Fungi and Insects

Defects due to fungi and insects in timber involve fungi, dryrot, and wetrot which are discussed as under.

Fungi in timber use the wood as their food and destroy the same. It acts on the wood tissues and cells and cause decay. There are two types of defects in wood because of fungi and insects which are known as dry rot and wet rot.

Dry rot is a type of fungus on dry wood which feeds on damp wood and breaks it down. Dry rot is so called because infected wood eventually becomes lighter in weight and takes on the appearance of being badly charred by fire, except that it is brown in color instead of black and crumbles under slight pressure. This fungus cannot develop in wood which has a sap content of less than 20% so that to prevent it, all that is really necessary is to use seasoned timber and to keep it dry.

Wet rot in timber is the decay due to dampness. The wood looks wet due to fungi attack on living trees. The effected positions of wood are reduced to a gray brown powder. Well seasoned wood, protected by painting etc., will avoid wet rot.

Insects such as beetles, borers and white ant attack the wood and render it of no use. Beetles are commonly found in temperate region and the field of tropical and non tropical regions. Beetles use timber as their food. Borers produce holes in the timber to find shelter for living. White ants or termites are very common in warm temperature countries. They attack the wood, and make it hollow from inside. The insect attack may be controlled through the use of insecticides. In another method, the timbers are placed in a kiln where steam and heat are used to suffocate the pests.

9.6 TIMBER PRESERVATION

It is highly essential to protect timber from attack of fungus and any damage from insect attack. Timber products require protection if it is exposed to weather such as doors, windows, poles etc. Extending the life of the timber through preservation is a much cheaper deal. The object of treating timber with a preservative is to render it immune to decay, even though it may become quite damp and to prevent attack by timber boring insects. Most timber preservatives belong to one of three main group tar-oil derivatives creosote, water soluble type and organic solvent chemicals.

9.7 CHARACTERISTICS OF A GOOD TIMBER

Timber is free from knots, insects attack, excessive moisture, discoloration, twisted fibers, cup and ring shake, sound, bright and free from any discoloration. It is solid with annual rings but not hallow in the center. Timber should be well seasoned for easily workable specific use. It should possess straight fibers and high fire resistance. It should not split when nails are driven in it. It should not clog with the saw teeth during the sawing operation. Timber should be highly suitable for polishing and painting.

9.8 FACTORS INFLUENCING TIMBER SELECTION

The factors influencing the selection of timber involve the quality of timber in terms of its durability, workability, weight, hardness, cohesiveness, elasticity, type of texture, type of grains, resistance to fire, resistance to various stresses, ability to retain shape, suitability for polishing and painting.

9.9 PLYWOOD AND APPLICATIONS

For the last so many years, the use of the plywood and other manufactured boards has, in varying degrees have replaced the use of solid timber in the making of furniture, fittings, paneling and many forms of constructional work. Plywood is generally made of three or more sheets of veneer glued together, with the grain of successive plys laid cross-wise. Since the strength of timber lies along the grain, when plys of veneer are bonded in opposing grain direction, strength is distributed to both length and breadth of the piece. The plywood can be obtained in much larger sizes without shrinkage and warping in comparison to plain wood. The molded plywood boats, television and radio cabinets can be formed from plywood. The plywood can withstand easily against humid condition. Plywood is lighter in weight and stronger across the grain than even the toughest hardwoods. Screws and nails can be driven close to the edge of plywood without any danger of splitting. High class surface finish can be are easily obtained on plywood.

The development of moisture and heat-resistant adhesives have contributed to the use of laminated members for heavy truss construction, to the gluing together of narrow boards to make wider ones, and to the making of finger joints by which short lengths are joined to make longer pieces. Plywood is used for many forms of construction, including sheathing, interior finish, sub flooring, under-roofing, paneling, flooring, cabinets, furniture, shelving, partitions, ceilings, containers such as baskets, boxes, crates, trunks into boats, toys, tables, woodenware and repair work in garages and basements.

9.10. MISCELLANEOUS MATERIAL USED IN CARPENTRY SHOP

There are a number of other materials used in carpentry shop besides timber. The main materials are dowels, nails, screws, adhesives, paints and varnishes. A brief description of such material is given as under.

Dowels

Dowels are wooden pieces of special nails kind generally made out from bamboos or other similar wood by the carpenter himself. They are used for fastening different wood structural components. Hole is initially drilled through the two pieces or parts to be joined together. After assembling of in proper position of the parts to be joined, the dowel is then driven through the parts.

Nails

Nails in wood work are made out of drawn wire of brass or copper or low carbon steel or malleable iron rods. Nails made from drawn wires are termed as wire nails and are produced from rods as clasp nails. The clasp nails possess a better holding capacity than wire nails. According to the use, the wire nails are subjected to light and medium work while the clasp nails are commonly used for heavy work. Nails are mainly used for reinforcing glued

joints and fastening different component of woods. Their size is specified by length and diameter. These are sold by weight in the market.

Screws

Screws are made from bright drawn wires or thin rods and they are used mainly for fixing the metallic fittings like hinges and hasps in wooden structure.

Adhesives

Adhesives is defined as the sticking substance such as glue, paste, cement and mucilage that is capable of holding wooden parts together by surface attachment permanently. It is commonly used to join together the boards edge-to edge to form a larger surface or face-to-face to increase the thickness. It is applied on large surface areas of material as when laying veneers and is also used to stick together relatively small surface areas such as wood working joints. An efficient adhesive or sticking paste or glue is one that maintains good bond between the wooden elements under the conditions of service that the joint has to withstand. It is required frequently for joining together the wooden boards edge to edge to form a larger surface or face to face to increase thickness in joinery work and many other common types of wood works. It is applied either cold or hot condition. The former is known as liquid or cold glue and is used when a slow and less strong setting is desired. When applied hot, it is known as cooked glue that enables a very strong and permanent type of joint between the adjacent layers of wood pieces. Few commercially available adhesives can be classified as casein glue, animal glue, vegetable glue, albumen glue, synthetic resins, poly-vinyl-acetate (PVA), paint and varnishes, rubber cement and plastic cement and few important such adhesives are briefly discussed as under.

Casein glue

Casein glue is made by adding an alkali to the curd of skimmed milk. It is commercially available in powdered form in the market. It can be made into a paste, while using, by adding water. It is thicker than animal glue but squeezes out of the joint quickly when pressed. This glue requires 15 to 20 minutes to set a wooden joint and therefore thus provides the carpenter sufficient time to glue and clamp his work. Casein glue is a commonly used adhesive which is very strong and water resistant. It is used specially in components which are continuously subjected to high humidity viz. furniture, boat making, veneering, beams and others wooden components.

Animal glue

This glue is made from hides, hoofs, bones and other waste parts of animals. These materials are refined and developed in form of sheets, flakes or powder. Before applying, the glue should be soaked in cold water over night and then heated. It is generally applied hot and sets very rapidly. It is also available in liquid form commercially which is applied cold i.e. it does not require any heating before application. An important point is to be noted that this glue should be applied immediately after heating. Repeated heatings should be avoided as this weakens the bond of the glue and also its fluidity is lost due to evaporation of water, rendering it thicker.

Vegetable glue

It is developed from the starch which is obtained from roots, grains and corns of trees by subjecting them with acid and by grinding to a powered form. It is mainly used in plywood work and it is not much suitable for general work

Albumen glue

It is prepared by adding an alkali to beef blood and is available in flakes forms in the market. During use they are dissolved in water in about an hour earlier, to found a liquid solution and it gives a very strong and water proof bond.

Synthetic resin glue

This glue is made from formaldehyde uric acid and other chemicals. It is available in generally powder form. Before use, it is thoroughly mixed with water to proper consistency. The commercial varieties of resin glue involve polyvinyl-resin glue in liquid form, plastic resin glue in powder form and resorcinol-resin. The polyvinyl glue is the fastest setting, strong, easy to use and it is extensively used in furniture and decorative work. The plastic resin glue is mainly used in plywood work. The resorcinol glue can be used for joining wooden parts which are constantly subjected to changing weather condition exposed to humid environment.

Paint and varnishes

They are commonly applied on wooden or metallic articles for the reasons to protecting the surfaces of wood or metal from the effects of moisture and weather change. They are used on surfaces for making them decorative in appearance.

9.11 CONSTITUENTS OF AN OIL PAINT

A good paint must have sufficient fluidity so that it can be easily spread by a brush over the surface. It should form a durable and wear-resistant film on drying over the surface of wood. It should retain its color on drying and under changing conditions of atmosphere and should not be affected much by moisture. It should give a pleasing appearance to the surface on drying. An oil paint comprises of various constituents such as base, vehicle, pigments, thinner and driver which are discussed as under.

Base is a major constituent of oil paint. It is finely ground powdered material which is mixed and then applied to the surface of the finished part to form the body of the paint. The functions of a paint base is to provide a sort of reinforcement to the film coated on the surface of finished parts after it dries, in order to make it hard and wear-resistant for long life. It also minimizes the chances of cracking of the coated film of paint after drying. Commonly used bases involve **white lead, red lead and iron oxide.**

The second constituent named as **vehicle** will act as a binder for the solid material and enables suspension of base and other coloring pigments in order to allow their even application on the prepared surface of the products and it facilitate its adherence to the latter. The well known vehicles are raw linseed oil, single or double boiled linseed oil, refined linseed oil, nut oil, stand oil and poppy oil.

The third constituent of oil paint function is **pigments** which provide various colors to the paints. They are generally available in fine powdered form and the best one is which does not change its color even on being exposed to sun and heat. The black color oriented common pigments are graphite, lamp black, and vegetable black. The blue color oriented common pigments involve Prussian blue, cobalt blue, indigo. The green color oriented common pigments is chrome green. The red color oriented common pigments are Indian red, red lead, vermilion, and venetian red. The brown color oriented common pigments are raw umber, burnt umber, raw sienna, burnt sienna. The black color oriented common pigments are chrome yellow and yellow achre.

The **Thinner** is a such a solvent which, when added to the paint, reduces its consistency and, thus, enhances its flow ability thereby facilitating an easy and quick spreading of paint over the surface of the job in the from of an uniform thin film. It is important to note that the thinner should not be added to the paint in an excessive quantity. The amount of a thinner in paint varies between 5 to 8 percent of the paint. The commonly used thinners are turpentine and naphtha.

The main objective or function of a **drier** in oil paint is to increase the rate of drying of the vehicles and hence the applied paints. The generally used driers are red lead, zinc sulphate, lead acetate, lead oxide and manganese sulphate.

9.12 COMMON TOOLS USED IN CARPENTARY SHOP

Commonly used tools to shape wood for various types of joints by driving in and driving out nail involve cutting and smoothening of wood surfaces. A broad classification of tools used in the wood working or carpentry shop are measuring and marking tools, supporting and holding tools, cutting tools, striking tools and miscellaneous tools. Most of commonly used tool and measuring devices as mentioned above are in chapter of fitting and sheet metal work also. Other some important such tools and instruments are discussed as under.

9.12.1 Marking and Measuring Tools

Marking in order to make wooden components of the required size or the marking of exact dimensions on the wooden piece is essential to produce quality jobs. A number of marking and measuring instruments namely Rules, Try Square, Combination Set, Bevel Gauge, Marking Gauge, Mortise Gauge, Cutting Gauge, Spirit Level, Trammel and Compass are commonly used for this purpose. Some of commonly used marking and measuring instruments are discussed as in chapter of fitting and sheet metal work under.

Rules

Rules are straight edge of wood or steel engraved in millimeters- centimeters or in inches-foot or in both. Theses are used to mark, measure the length, widths and thicknesses of wood part. Figs. 9.4.-9.6 show steel rule, folding rule and flexible steel rule. These rules are available in different sizes and designs. Metallic taps bearing sizes 6″, 12″ or 18″ are used for general measuring work. For example 24″ folding tape and 5″ or 6″ steel tape are used measuring larger dimensions. An important small instrument in any shop is a good quality straight-edge bench rules. These rules are manufactured of either metal or wood. They are used to check for straightness and to measure and mark straight lines. The bench rule may be graduated in inches, millimeters or both. The length of the bench rule may be 12″, 24″ or 36″. The 36″ rule is called yardstick. Another type of rule is folding two-foot rule which is more convenient than a straight 24″ rule. The zigzag rules are used to measure longer stock when exact measurements are not so important. One of These rules, when open may be of usually 6 or 8 feet long. The push pull steel tape or tape rule is a very compact metal rule that comes in lengths of 6, 8 or 10 feet. There is a hook at the end to slip over the edge of the bold. It is flexible to bends easily and can measure curved surfaces too. It is very good for measuring the inside depth of the hole of components also.

Try Square

Try square is generally utilized for measuring and checking of squareness, perpendicularity, dimensions, testing of finish of planned surfaces and drawing parallel and perpendicular lines.

The steel blade and metallic or wooden handle of try square are at right angles to each other. Try square is used for testing the level, edge and square ness of the wooden surfaces. It is also used for marking lines across the face or edge of wooden block. There are graduations along the blade of the rule that are used for measuring and marking purposes on the wooden jobs. The blade of try square is made of hard tempered steel of non rusting kind. It is seldom used for hammering work.

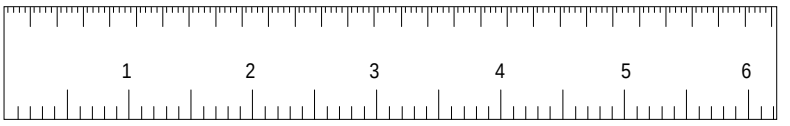


Fig. 9.4 Steel rule

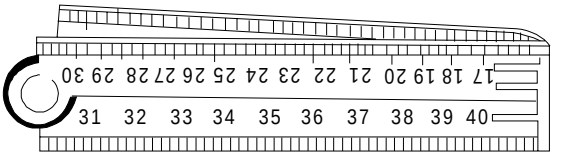


Fig. 9.5 Folding rule

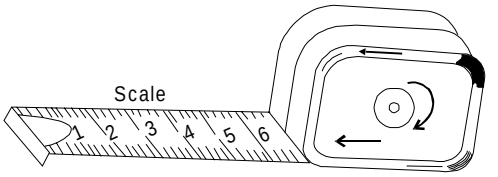


Fig. 9.6 Flexible steel rule

Combination Set

Combination set is frequently used in the carpentry shop for different kind of measurements. It consists of blade and a head. The blade has a groove cut along its length so that it can slide into the head. One side of the head makes a 90° angle with the blade and the other side a 45° angle. It can be making, measuring and setting different angle. It also acts as a try square, angle gauge to set 45° angles, a depth gauge and level checking tool.

Bevel Gauge

Bevel gauge is also known as an adjustable bevel which is mainly used for marking, measuring and inspecting angles from 0 to 180 degree. Its blade can be adjusted and set to any desired angle.

Marking Gauge

The marking gauge is made of wood which is important tool utilized to make lines at a uniform distance from the edge of a board or piece of work and is used principally when preparing wooden components to size before jointing. The marking gauge like the mortise gauge and cutting gauge in use should be positioned correctly. For marking purposes, the gauge is drawn towards the body or pushed away from it but in either case, if the spur does not trail. It will tend to jump and run with the grain. Thumb screw of the marking gauge locks the stock at any position. The spur made of hardened steel should be ground to a fine point. And for ease of working, it should not project too far from the face of the stem. It is

commonly used to mark or scribe line parallel to and at any desired distance from a finished edge or face of a surface

Cutting Gauge

Cutting gauge is similar in construction to the marking gauge but having a knife in place of the marking pin or spur. It can be utilized for gauging and marking deep lines across the grain of wood in thicker sections. It is also used for setting out the shoulder-lines of lap dovetails and similar joints, as well as for trimming veneers parallel to the edge of surface before laying a cross-band. Cross banding is the laying of a strip of cross-grained veneer around the edge of a surface for example the edges of a table top, box lid or drawer front. This gauge is very useful for making very small rebates to receive inlay lines and may be used in place of marking gauge. Inlay lines are thin strips of wood which can be glued into a rebate cut around the edge of a veneered surface.

Mortise Gauge

9.7 shows a mortise gauge. This is an improved form of marking gauge which consists of main components as fixed pin, sliding pin, brass strip, stem, rose wood stock and thumb screw. The fixed pin of the gauge is attached to a short brass strip which is screwed to the stem. The sliding pin is fixed to a long brass strip or slider is adjusted by means of a thumbscrew. The threaded portion of which engages in a cylindrical nut which is embedded in the stem. The stock is locked in position by a metal set screw. This gauge is used for marking out of the parallel sides of a mortises or tenons and other similar joints.

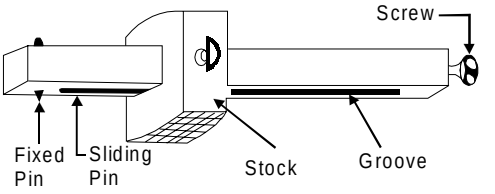


Fig. 9.7 Mortise gauge

9.12.2 Holding And Supporting Tools

Sometimes it is desirable to support and gold a wooden board in a special manner while the work is being carried out. For these purposes, various supporting and holding devices are needed some of which are discussed as under.

Work Bench

Every carpenter generally needs a good solid bench or table of rigid construction of hard wood on which he can perform or carry out the carpentry operations. Work bench should be equipped with a vice for holding the work and with slots and holes for keeping the common hand tools. One jaw of the vice is tightened to the table and is kept moveable for holding the articles Work benches are built solidly with good heavy tops for providing a good working surface for cutting, as well. The vice on the bench is equipped with an adjustable dog that is, a piece of wood or metal can be moved up and down in the outside jaw of the vice.

Carpenter Vice

Carpenter vice (Fig. 9.8) is very important tool in wood working shops for holding wooden jobs. There are several varieties of vices, each possessing its own particular merit.

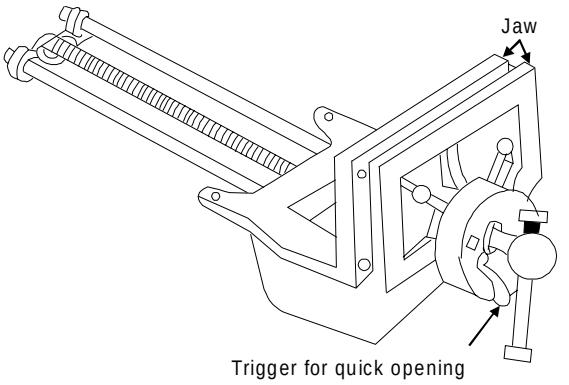


Fig. 9.8 Carpenter vice

Clamp

Clamps are commonly used in pairs in gluing up operations at the final assembly of wood joinery work. These clamps can provide pressure required to hold joints together until they are secured due to the setting of glues. Clamps are of two types namely plain rectangular bar type and T-bar type. The former is made of mild steel and is usually rectangular in section. The later may be of T-section, which can easily afford greater rigidity under stress. The coarse adjustment jaw may be located in any position on the bar by means of a steel pin which fits into any of the holes drilled at intervals along the bar. The fine adjustment jaw of the sash clamp is moved along the bar by a square threads screw which passes through a special nut fixed to the end of bar. Considerable pressure can be applied by turning the screw with the Tommy bar for holding a wooden job. Both jaws of the sash clamp are generally made of malleable cast iron which is tougher and less brittle than ordinary cast iron. There are other similar types of such clamps named as rack clamp, screw clamps, light duty parallel clamp, adjustable bar clamp (Fig. 9.9), G or C-clamp (Fig. 9.10), and double bar clamp which are useful for holding different sizes and shapes of wooden jobs.

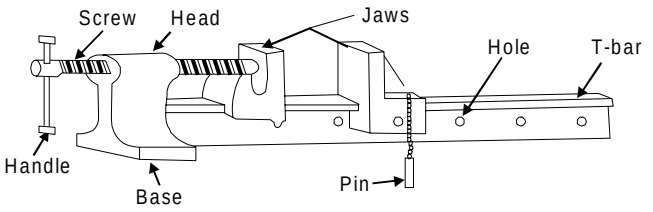


Fig. 9.9 Bar clmap

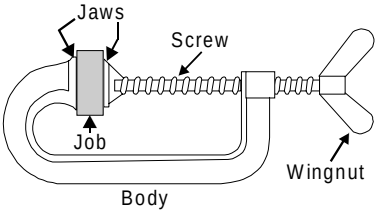


Fig. 9.10 G or C-clamp

9.12.3 Cutting Tools

Various kinds of cutting tools namely various kinds of saws, planes, chisels, scraper, files, and rasp adze and axe and boring tools such as brace and bits, bradawl, auger, gimlet are used in the carpentry shop. Few important types of cutting tools are described as under.

9.12.3.1 Saws

Saws are wood cutting tools having handle and a thin steel blade with small sharp teeth along the edge. They are utilized to cut wood to different sizes and shapes used for making the wooden joints that hold parts together. They can be further classified into three major types namely hand Saws (Rip, Cross-cut, Panel, Keyhole and, Pad saw), Snuff Saws (Tenon

and Dovetail) and Frame Saws (Coping, Bow and Fret). Few important types of saws are shown in Fig. 9.11. Some of them are described as under.

Rip Saw

The rip saw is shown in Fig. 9.11. It is used for cutting timber along the grains. The teeth of rip saw are chisel-shaped and are set alternately to the right and left. A 24″ long point saw is a good for sawing work. Depending upon whether the saw is designed to rip or cross-cut, the shape of the teeth will also vary. In the case of a ripsaw, the teeth are shaped like chisels.

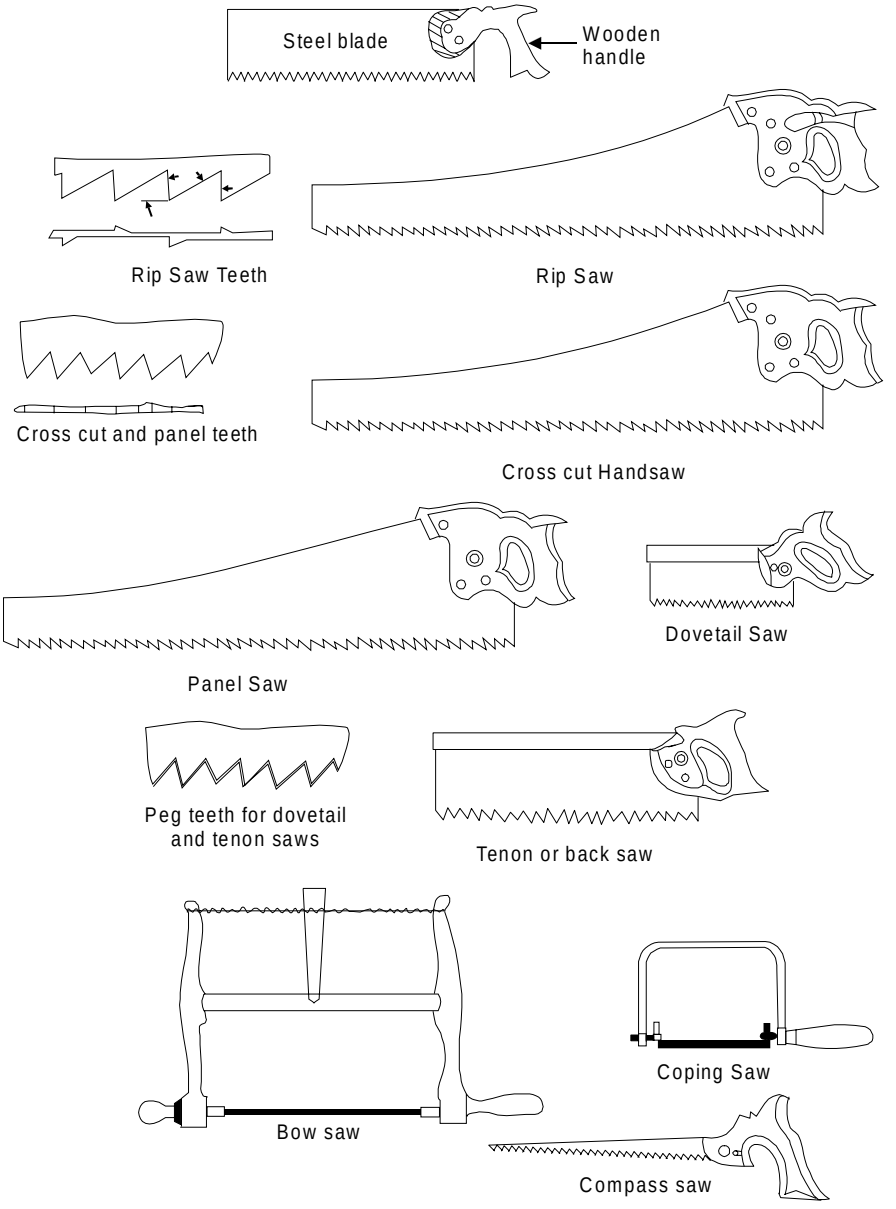


Fig. 9.11 Few important types of saws

Crosscut Saw

Cross cut saw is shown in Fig. 9.11 which is similar to rip saw in shape. It is primarily designed for cutting across the grains of wood. The teeth are knife shaped and bent alternately to the right and left for making the saw to cut wider than the blade. The saw cut is called the kerf. Since the kerf is wider than the blade, the blade will not stick as the sawing is done. The saw teeth may be coarse (with only 4 or 5 teeth per inch) or fine (with ten or twelve teeth per inch). A jaw for general purpose cutting should have about eight or nine points per inch (there is one more point than teeth per inch) and should be about 24 inches long.

Turning Saw

The turning saw is similar to the copying saw which is designed for cutting curves, scrolls and roundings on wooden jobs. It is used chiefly on heavier work where long fast stroke and less accuracy of cutting are required. The thin blade of the turning saw is removable. This saw can be pivoted between the handles. The saw generally cuts in the pulling stroke.

Dovetail Saw

Dovetail saw is shown in Fig. 9.11 which is little and is closely similar as related to the backsaw or tennon saw. It is lighter and however possesses a thinner blade and finer teeth. The handle is round, to provide a delicate grip for fine cutting. This saw is used where absolutely finer and delicate cutting is required in wood work.

Compass Saw

Compass saw carries a tapered blade which is long as shown in Fig. 9.11 which is one of the special saw having thin, narrow and flexible blade. With a blade resembling the beak of a swordfish, this type of saw is commonly used for making cutouts on the inside surface of a piece of work. A hole is first bored inside the portion which is to be cut out and the pointed compass saw is pushed into the hole to start the sawing operation. Its blade contains about 12 teeth per cm length

Keyhole Saw

The keyhole saw is used in the same manner as the compass saw. For this reason it is generally employed for fine internal and intricate work where the compass saw would be too big and clumsy for the carpentry job.

Hacksaw

Hacksaw is shown in Fig. 9.12 which consists of steel frame and a hacksaw blade. While essentially designed for cutting metal, this tool comes in for a variety of uses in the wood working shop. The frame of hacksaw is designed in different ways, some with pistol grips, others with handles similar to those used on a conventional saw and others with turned handles. Blades of hacksaw are detachable and can be obtained with teeth of varying coarseness.

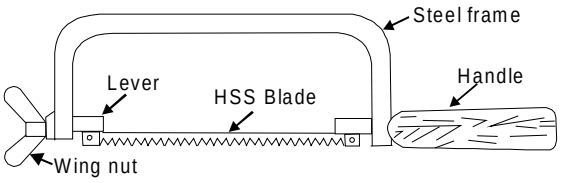


Fig. 9.12 Hacksaw

9.12.3.2 Planes

A plane is a special tool with a cutting blade for smoothing and removing wood as shavings. It is just like a chisel fixed in a wooden or steel body. Fig. 9.13 shows a simple plane. The modern plane has been developed from the chisel. They can also be classified as jack plane, smooth plane, jointer plane, trying plane, rabbit plane, circular plane and fore plane. Few important planes are discussed as under.

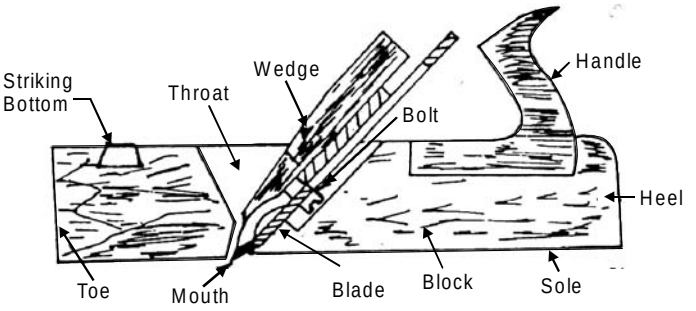


Fig. 9.13 Simple plane

Jack Plane

Jack plane is most commonly used plane which is shown in Fig. 9.14 which comprises of its body about 40 cm long, blade 5-6 cm wide and handle. It is good for rough surfaces that require a heavier chip. It is ideal for obtaining a smooth and flat surface. There are actually forty-six different parts of jack plane, the carpenter needs only acquainted with the working or regulating parts. The main working parts are the cutting blade or plane iron. The adjusting nut is operated to raise or lower the blade and the adjusting lever which regulates the blade so as to make possible an even or slanted cut. The cutting blade of the jack plane is guarded with a metal cap which is adjusted on top of the blade to within about 2.4 mm of the cutting edge. The metal cap of the jack plane eases the cutting action by curling and breaking off the wood shavings evenly, thus preventing splitting or splintering of the wooden part.

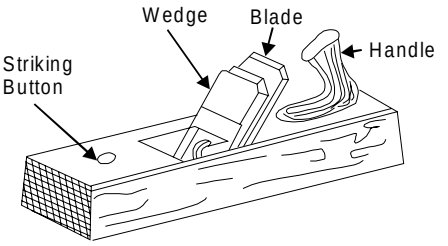


Fig. 9.14 Jack plane

Smoothing Plane

Smoothing plane is shown in Fig. 9.15 which is somewhat smaller than the jack plane, measuring between 6 and 10 inches in length. It is a fine utility tool, especially useful for planning end grain, chamfering, and other edge shaping of wooden part. This plane is also used for cleaning up after gluing and assembly, but owing to its short length should not be used for producing very true surfaces.

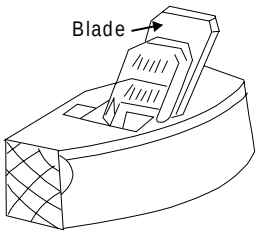


Fig. 9.15 Smoothing plane

Jointer Plane

When a fairly long board is to be planed absolutely straight and square along the edge, it is easier to obtain a straight and level surface with the jointer plane in comparison to any other type of plane. This plane is made up in various sizes but the most popular type of jointer plane is 24 inches in teeth.

Trying Plane

The wooden trying plane is shown in Fig. 9.16 which is similar in construction to the jack plane except that its blade is wider and much longer than jack plane. Its mouth is also narrower than that of the jack plane.

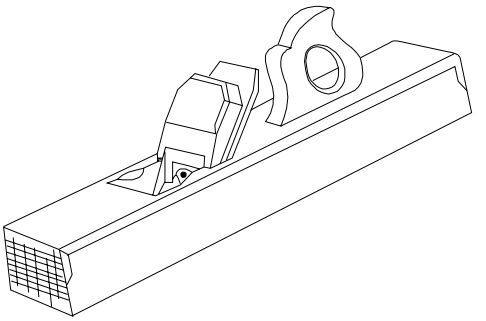


Fig. 9.16 Trying plane

Rabbet Plane

Rabbet plane is shown in Fig. 9.17 which is used for sinking one surface below another and shouldering one piece into another. If the edge of a piece of wooden board is to be rabbeted, this plane is being generally used. The side guide and the cutting blade of the rabbit plane may be adjusted so as to cut rabbets of varying widths and depths. The plane is useful for various types of edge shaping. Rebate or rabbet means a recess or step cut into the edge or end of a wooden board.

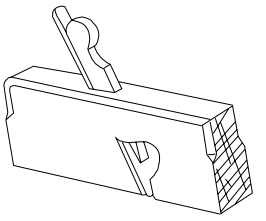


Fig. 9.17 Rabbet plane

Circular Plane

The shape of circular plane adapts it for planning either convex or concave surfaces and for shaping round edges. This plane may be adjusted so that the flexible bed will conform to circles of various sizes.

Fore Plane

This plane may be said as a junior jointer plane. It is slightly shorter than the conventional jointer plane. It is mainly used for planning edges of medium length.

9.12.3.3. Chisels

A Chisel (Fig. 9.18) is a strong sharp edge cutting tool with a sharp bevel edge at one end. Its construction is composed of handle, tang, ferrule, shoulder, and blade. Chisels are generally **made up of high carbon steel.** They are used to shape and fit parts as required in joint making.

A gouge (Fig. 9.19) is a curved chisel. It may be outside or inside ground. Outside ground gouges are called firmer gouges and inside ground gouges are called scribing gouges. The scribing gouges are made long and thin, they are known as paring gouges. Several varieties

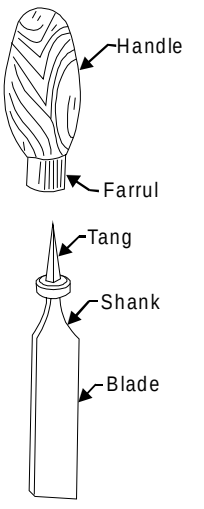


Fig. 9.18 Chisel

of chisels are available, each having special characteristics which fit it for its special use. There are two types of construction employed in the making of chisels named as tang and socket types. The tang chisel is made with a ranged or pointed end which pierces into the handle. The socket chisel reverses the process by having the handle fit into the socket collar on the blade.

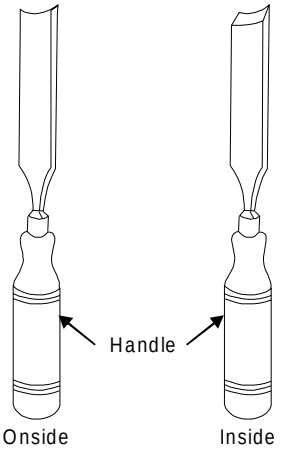


Fig. 9.19 Gouge

Firmer Chisel

Firmer chisel is shown in Fig. 9.20 which possesses a blade of rectangular section. It consists of the following parts blade made of cast tool steel and it is used for general bench work. The shoulder of the chisel prevents the tang from being driven farther into the handle when the chisel is struck with a mallet. The ferrule is short length of brass tube (mild steel tube in the case of some mortise chisels) which fits tightly over the lower end of the handle, and helps to prevent its splitting by the tang. The tang is not hardened as to fit in the handle. The handles turned from ash or beech wood as these timbers are resistant to splitting.

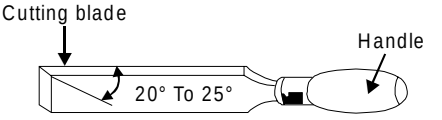


Fig. 9.20 Firmer chisel

Beveled edge firmer chisel

Beveled edge firmer chisel (Fig. 9.21) is identical to the firmer chisel except that the edges of the back of the blade are beveled. This enables the chisel to be used for cutting right into the corner of acute-angled wood work such as the base of a dovetail.

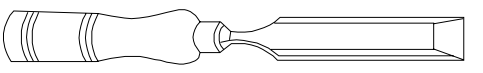


Fig. 9.21 Beveled edge firmer chisel

Paring Chisel

Paring chisel (Fig. 9.22) has a longer and usually slightly thinner blade than firmer chisel. It may be obtained with a blade of rectangular or beveled edge section and is used in

pattern making and where long accurate paring is required. The paring chisel should not be struck with a mallet. This chisel is intended for manipulation by hand only, and not for driving with a mallet like a firmer chisel for cutting of wooden jobs.

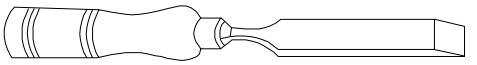


Fig. 9.22 Paring chisel

Mortise Chisel

Mortise chisel (Fig. 9.23) is designed for heavy work. A mortise chisel has a blade which is very nearly square in section and so may be used as a lever for removing chips and will withstand heavy blows from a mallet. Various types of handles are fitted to mortise chisel depending upon use. Mortise chisel has an oval beech handle, whilst the heaviest type of all has a socket handle. This socket replaces the ferrule and affords greater resistance to splitting when used for very heavy work. The leather washer acts as a shock absorber.

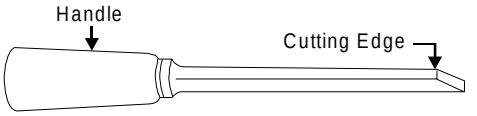


Fig. 9.23 Mortise chisel

9.12.3.4. Scraper

The scraper for wooden work is used in carpentry shop. It is used after planning to obtain a smooth surface before final glass papering. Where the grain in wood is particularly twisty so that even a finely set plane tends to tear it, a sharp scraper will be found most useful to tackle this problem. It is also used for cleaning up veneered work as its curved edges are used for cleaning up large molding of concave section and other similar work. The scraper is held as the thumbs being positioned low down and pushed forward to curve the blade so that the center of the edge rather than the outer corners comes into contact with the surface of the wood. A sharp scraper will produce fine shavings on wooden surfaces.

9.12.3.5. Files and Rasps

Files and Rasps are shown in Fig. 9.24. They are of used for maintaining other wood working tools and equipment. They are made of hardened tool steel which is tempered and they should never be dropped as they are very brittle to break. They are of various types depending upon their size, shape, cuts and degree of their coarseness.

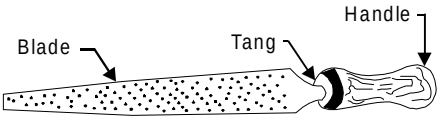


Fig. 9.24 Rasps

9.12.3.6. Adze

An adze (Fig. 9.25) is used for rough cutting, squaring, to chop inside curves and to produce concave surfaces. Its outer face is convex, inner face concave and edge is beveled to form a cutting edge. It is made of carbon steel.

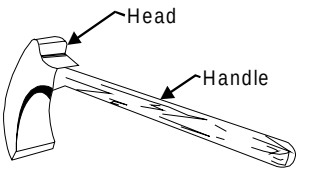


Fig. 9.25 Adze

9.12.3.7. Axe

An axe is used for splitting the logs and for removing bark from the wood. It is made of carbon steel and both sides are beveled to form a cutting edge. Its one side is plane and the other is beveled to form a cutting edge. It is used to make the surface roughly plane.

9.12.3.8. Boring Tools

Boring is cutting a hole in wood with a tool called a bit. Holes of 6 mm size or larger are bored. Holes of 6 mm size or smaller are drilled. Boring is the first step in making any kind of shaped opening or making holes. The commonly used boring tools bits are discussed as under.

The center bit

The center bits (Fig. 9.26) are available in sizes ranging .from 4 mm to 50 mm and are useful for boring holes through thin wood. They are not recommended for deep boring as it has a tendency to wander or drift as a result of varying grain texture and direction in wood. The screwed center of the improved center bit helps to draw the bit into the wood and therefore requires less pressure to obtain a cutting action.

Fig. 9.26 Centre bit

Auger bits

The auger bits (Fig. 9.27) are also known as twist bit. They are the most commonly used hole making tools used in wooden wood. They may possess a single twist auger bit or a double-twist auger bit. These bits are more costly than center bits. They can produce holes easily and accurately from 5mm to 35 mm in diameter in wooden jobs. The hollow features are important in both types of auger bits, because the parallel sides of the bit help to prevent drifting. And the twisted form of the body of the bit helps in the removal of cuttings. Both these bits have two cutters and two spurs as well as a screw center for quick and clean boring action in wood work.

Fig. 9.27 Auger bit

Countersink bits

Countersink bit (Fig. 9.28) is used for countersinking the predrilled holes to placement of heads of screws.

Shell and spoon bit

Shell and spoon bits are the traditional kinds of bit which are now superseded by the carpenter's twist drills or bits.

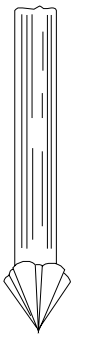


Fig. 9.28 Countersink bit

Expanding bits

These are commonly used forms of screw center bit which are adjustable for cutting holes of from 15 mm to 75 mm in diameter. The two combined cutter-spurs are provided in each case to cover the range of hole sizes.

Forstner bits

These are used for boring clean sided stopped holes of flat bottom kind.

Snail bits

The snail bits have only one cutter which gives a clean cutting action.

Rose bits

The rose bit tends to scrape rather than cut. It is generally used on soft metals in addition to wood.

Bradawl

Bradawl is used for making fine holes, especially nail holes in soft woods. The cutting edge of the blade, which is sharpened equally from both sides, is placed across the grain so that the wood fibers are severed and not merely forced outwards. The blade is forced into the wood and it is then allowed to twist for enlargement of the diameter of the hole being bored and then finally removed. The cutting edge of the blade of bradawl is flared out to give clearance to the body of the blade which is fixed to the handle by means of a square-tapered tang. A brass ferrule is fitted to prevent the tapered tang splitting the handle when being pushed into it. The blade of bradawl is shouldered to prevent its being forced further into the pear-shaped handle which is usually turned from ash, box or wood.

Auger

The auger (Fig. 9.29) is a carpentry hand tool (made up of steel bar) and is used to make holes in the wooden jobs. It possesses a screw point to center the tool at the point where hole is to be produced in the wooden part. Fluted body of the auger is to allow removal of wooden chips from wooden jobs using handle to apply pressure to rotate the auger for making the hole. Holes up to 25 mm diameter can be produced.

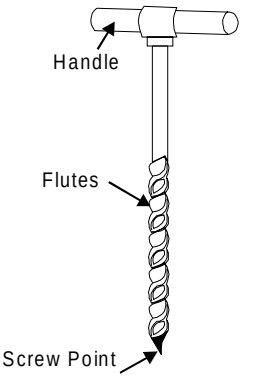


Fig. 9.29 Auger

9.12.4 Striking tools

Mallets and various types of hammers are generally used as striking tools in carpentry shop. A hammer delivers a sharp blow, its steel face being likely to damage the chisel handle whereas the softer striking surface such as mallet will give better result. Some of important such tools are discussed as under.

Mallet

A mallet is a short handled wooden hammer with a large head as shown in Fig. 9.30. It is used to strike a chisel for heavy cutting waste wood, from joints such as mortises and halving joints and also for removing unwanted, wood on shaped work etc. Mallet is frequently also used to tap parts of a project together during the assembly process.

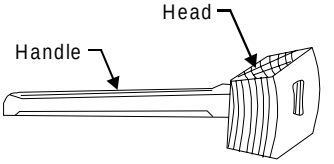


Fig. 9.30 Mallet

Hammers

Warrington, peen and claw hammers are generally used by carpenters. They are described as under.

Warrington Hammer

Warrington hammer (Fig. 9.31) is used for knocking in nails, assembling joints and setting wooden plane blades. The head is forged from tool steel and is obtainable in various weights. The face of hammer is hardened, tempered and ground slightly convex. The center part of the head is not hardened as a precaution against breakage in use through its being to brittle. The handle is made of wood and is oval in cross-section to have a comfortable grip. The end of the handle fits into a hole in the head and is held in position by wooden or metal wedges which open out the grain, thus securely locking the two parts together.

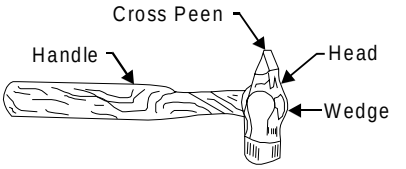


Fig. 9.31 Warrington hammer

Peen Hammer

The peen hammer is used for striking nails where the use of the face is impracticable. The peen hammer is very light and is used for driving the panel pins and fine nails.

Claw Hammer

The claw hammer is shown in Fig. 9.32. One of its end possesses curved claw which is used for extracting nails in order to provide the extra strength needed for this levering action. The other end is used for light striking work. A strong handle on claw hammer is always necessary for carrying out the task.

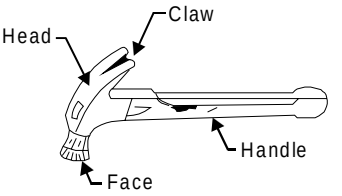


Fig. 9.32 Claw hammer

9.12.5 Miscellaneous Tools

Other some miscellaneous carpentry hand tools that are also used in carpentry shop include screw driver, pincer and fasteners which are discussed as under.

Screw Driver

Screw driver (Fig. 9.33) is used to drive the screws into the wood. The tip of screw driver should be slightly hollow-ground so that it will fit accurately in the slot in the screw-head. The blade of a screwdriver is made of hardened tempered tool steel so that its tip can withstand the great strain put upon it while screwing. The tang of screw driver is not hardened. It is wide and rectangular in section so that it will restrict the twisting action put upon it during use. The ferrule is slotted to receive the tang and to hold it firmly in place in the handle. The handle, if made of wood, is usually pear-shaped or if made of unbreakable plastic, is generally of a fluted cylindrical shape. Some screwdrivers are fitted with a ratchet device used for clockwise anti-clockwise turning.

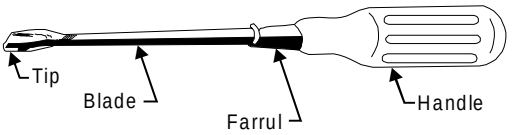


Fig. 9.33 Screw driver

Pincer

Pincers are commonly used for withdrawing nails. They are made of cast steel, the jaws being hardened. The end of one of the arms is shaped to form a claw for removing nails. The nail head is firmly gripped between the jaws as the long arms permit considerable pressure to be exerted by them. The nail is extracted from the wooden body by a leveling action, using the curved side of one of the jaws as a fulcrum. A small block of wood placed between the steel jaw and the work prevents damage to the surface of the wood.

Various types and sizes of screws are available in different sizes from 6 mm to 150 mm and are sold in market by numbers. A hole is drilled before putting the screw and then same is driven into former by means of a screw driver.

Bolts and nuts are used only where very heavy components are to be fastened together viz., wooden roof trusses and folding type furniture etc. The standard B.S.W. mild steel bolts and nuts are used.

9.13 COMMON WOOD JOINTS

All wooden objects whether doors, windows, furniture, pattern, core boxes, handicrafts, toys, cots, etc., are all assembled with joints. The various common used wood working joints are given through Fig. 9.34 to Fig. 9.41.

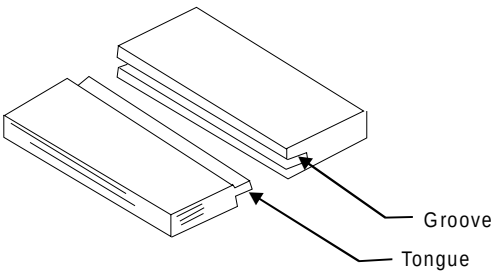


Fig. 9.34 Groove and tongue joint

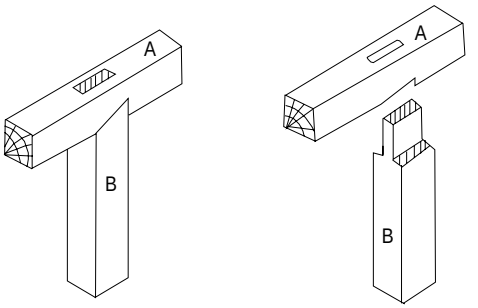


Fig. 9.35 Mortise and tennon joint

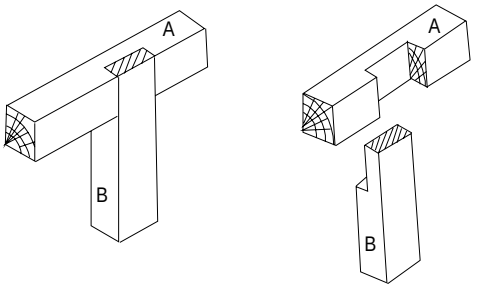


Fig. 9.36 T-lap joint

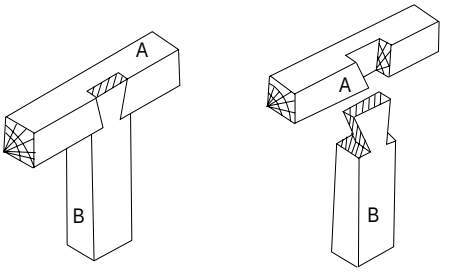


Fig. 9.37 Open or through dove-tail joint

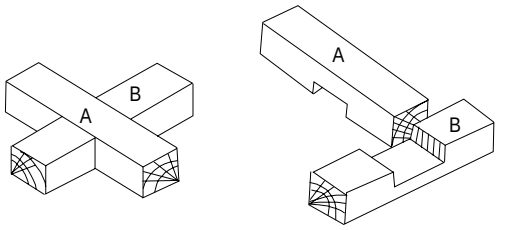


Fig. 9.38 Cross-lap joint

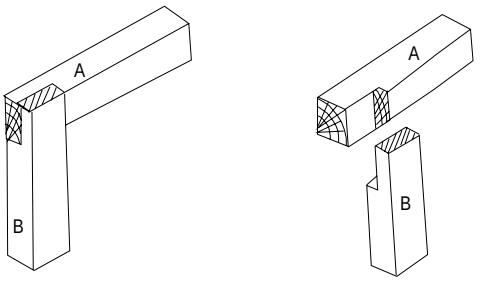


Fig. 9.39 Corner-lap joint

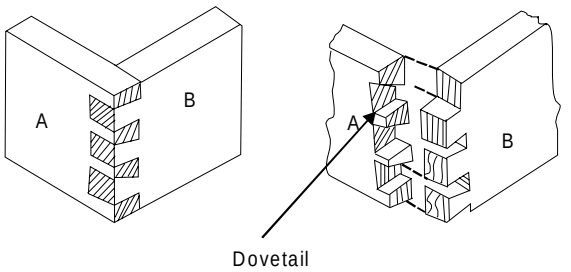


Fig. 9.40 Dovetail joint

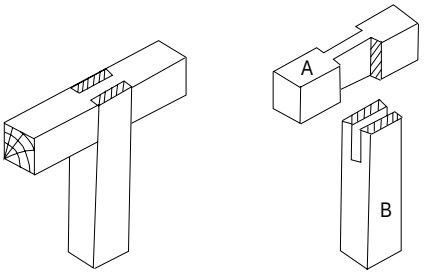


Fig. 9.41 Briddle joint

9.14 CARPENTRY MACHINES

Wood working machines are employed for large production work. These possess the following advantages over the hand tools.

1. The carpentry machines help to reduce fatigue of carpenter.
2. The carpentry machines are used for production work.
3. The carpentry machines save time and are used for accuracy work.
4. They are used for variable job variety and more designs are possible.

Different machines are needed to save time and labor in carpentry work for various quick wood working operations especially for turning and sawing purposes. The general wood working machines are wood working lathe, circular saw and band saw. These machines are discussed as under.

1. Wood Working Lathe

A general wood working lathe is shown in Fig. 9.42 which resembles roughly to an engine lathe. It consists of a cast iron bed, a headstock, tailstock, tool rest, live and dead centers and drawing mechanisms. The long wooden cylindrical jobs are held and rotated between the two centers. The tool is then fed against the job and the round symmetrical shape on the jobs is produced. Scrapping tool and turning gauge are generally used as a turning tool on a woodworking lathe.

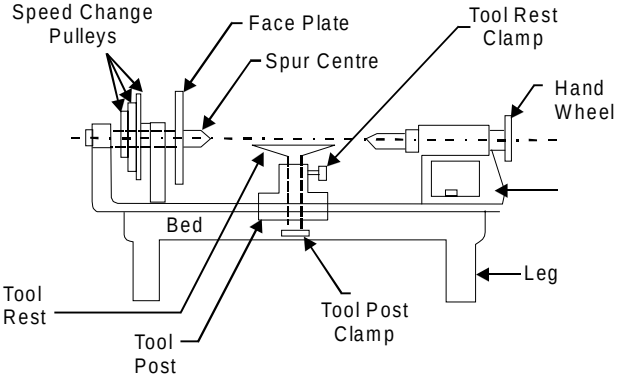


Fig. 9.42 Wood turning lathe

2. Circular Saw

A circular saw is shown in Fig. 9.43. It is also called as table or bench saw which is used to perform various operations such as grooving, rebating, chamfering etc. It consists of a cast iron table, a circular cutting blade, cut off guides, main motor, saw guide, elevating hand wheel, tilting hand wheel etc. The work is held on the table and moved against the circular saw to perform the quick and automatic sawing operation and other operation on wood as said above. The principal parts include the frame, arbor, table, blade, guides for taking cuts, guards and fencing.

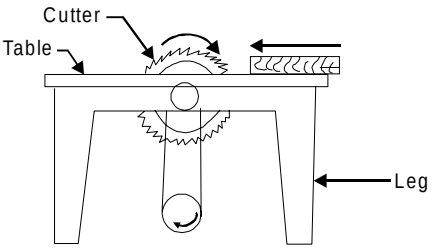


Fig. 9.43 Circular saw

3. Band Saw

Band saw is shown in Fig. 9.44 which generally used to cut the heavy logs to required lengths, cutting fine straight line and curved work. It consists of a heavy cast bed, which acts as a support for the whole machine, a column, two wheel pulleys, one at the top and other at the bottom, an endless saw blade band, a smooth steel table and guide assembly. It is manufactured in many sizes ranging from little bench saw to a larger band saw mill.

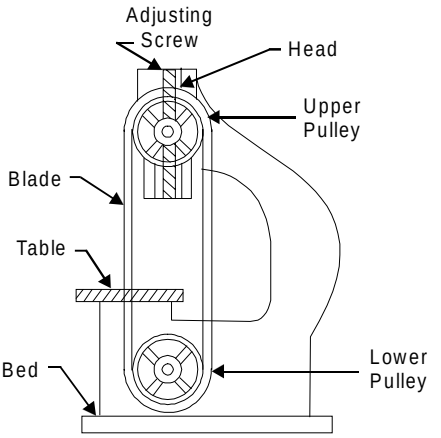


Fig. 9.44 Band saw

9.15 COMMON SAFETY IN CARPENTRY SHOP

There are some general safety precautions to be taken care of while working in carpentry shop. Some of which are discussed as under.

1 Before starting any wood working machine, it should be ensured that all the safety guards are in proper places and secured well.

2 While working on a circular saw, one should not stand in a line with the plane of the rotating blade and always keep your fingers always away from the reach of blade.

3 The wooden pieces should not be fed to the sawing machines faster than the cutting speed of the machine.

4 While working on wood lathes, the job should be properly held.

5 One should not use defective or damaged carpentry tools while carrying out carpentry work.

6 Nails, screws should be properly kept in a box for proper house keeping.

7 Sufficient safety precautions are to be taken for preventing fire in the carpentry shop.

8 No carpentry tools should be thrown for saving time in handling.

9.16 QUESTIONS

1. What is the difference between hard and soft wood?
2. Describe the various methods of seasoning of timber.
3. Define exogenous trees and endogenous trees.
4. What is the difference between wood and timber?
5. Describe the various methods of conversion of timber.
6. What are the characteristics of a good timber?
7. Sketch the cross-section of an exogenous tree. Discuss the various parts of this tree.
8. Explain in brief the various defects in timber.
9. Describe a few methods of preservation of timber in brief, and why is it necessary?
10. What are the commercial sizes in which the timber is sold in the market?
11. Explain in brief with neat sketches the various types of measuring tools used in carpentry shop.
12. Discuss briefly with neat sketches the various types of cutting tools used in carpentry shop.
13. Discuss briefly the setting and sharpening of a carpentry tool.
14. Discuss briefly the various boring tools used in a carpentry tool.
15. Discuss briefly with neat sketches the various planning and striking tools.
16. Sketch the various wood working joints.
17. Explain the following carpentry processes in brief.

    (*i*) Marking (*ii*) Sawing, (*iii*) Planning

    (*iv*) Boring, (*v*) Grooving, (*vi*) Chiseling
18. Explain the following wood working machines in brief.

    (*i*) Wooden lathe, (*ii*) Circular saw

    (*iii*) Band saw, (*iv*) Planer
19. What are the general safety measures used in carpentry shop?

10
CHAPTER

PATTERN AND CORE MAKING

10.1 PATTERN

A pattern is a model or the replica of the object (to be casted). It is embedded in molding sand and suitable ramming of molding sand around the pattern is made. The pattern is then withdrawn for generating cavity (known as mold) in molding sand. Thus it is a mould forming tool. Pattern can be said as a model or the replica of the object to be cast except for the various al1owances a pattern exactly resembles the casting to be made. It may be defined as a model or form around which sand is packed to give rise to a cavity known as mold cavity in which when molten metal is poured, the result is the cast object. When this mould/cavity is filled with molten metal, molten metal solidifies and produces a casting (product). So the pattern is the replica of the casting.

A pattern prepares a mold cavity for the purpose of making a casting. It may also possess projections known as core prints for producing extra recess in the mould for placement of core to produce hol1owness in casting. It may help in establishing seat for placement of core at locating points on the mould in form of extra recess. It establishes the parting line and parting surfaces in the mold. It may help to position a core in case a part of mold cavity is made with cores, before the molding sand is rammed. It should have finished and smooth surfaces for reducing casting defects. Runner, gates and risers used for introducing and feeding molten metal to the mold cavity may sometimes form the parts of the pattern. The first step in casting is pattern making. The pattern is a made of suitable material and is used for making cavity called mould in molding sand or other suitable mould materials. When this mould is filled with molten metal and it is allowed to solidify, it forms a reproduction of the, pattern which is known as casting. There are some objectives of a pattern which are given as under.

OBJECTIVES OF A PATTERN

1 Pattern prepares a mould cavity for the purpose of making a casting.
2 Pattern possesses core prints which produces seats in form of extra recess for core placement in the mould.
3 It establishes the parting line and parting surfaces in the mould.
4 Runner, gates and riser may form a part of the pattern.

5 Properly constructed patterns minimize overall cost of the casting.
6 Pattern may help in establishing locating pins on the mould and therefore on the casting with a purpose to check the casting dimensions.
7 Properly made pattern having finished and smooth surface reduce casting defects.

Patterns are generally made in pattern making shop. Proper construction of pattern and its material may reduce overal1 cost of the castings.

10.2 COMMON PATTERN MATERIALS

The common materials used for making patterns are wood, metal, plastic, plaster, wax or mercury. The some important pattern materials are discussed as under.

1. Wood

Wood is the most popular and commonly used material for pattern making. It is cheap, easily available in abundance, repairable and easily fabricated in various forms using resin and glues. It is very light and can produce highly smooth surface. Wood can preserve its surface by application of a shellac coating for longer life of the pattern. But, in spite of its above qualities, it is susceptible to shrinkage and warpage and its life is short because of the reasons that it is highly affected by moisture of the molding sand. After some use it warps and wears out quickly as it is having less resistance to sand abrasion. It can not withstand rough handily and is weak in comparison to metal. In the light of above qualities, wooden patterns are preferred only when the numbers of castings to be produced are less. The main varieties of woods used in pattern-making are shisham, kail, deodar, teak and mahogany.

Shisham

It is dark brown in color having golden and dark brown stripes. It is very hard to work and blunts the cutting tool very soon during cutting. It is very strong and durable. Besides making pattern, it is also used for making good variety of furniture, tool handles, beds, cabinets, bridge piles, plywood etc.

Kail

It has too many knots. It is available in Himalayas and yields a close grained, moderately hard and durable wood. It can be very well painted. Besides making pattern, it is also utilized for making wooden doors, packing case, cheap furniture etc.

Deodar

It is white in color when soft but when hard, its color turns toward light yellow. It is strong and durable. It gives fragrance when smelled. It has some quantity of oil and therefore it is not easily attacked by insects. It is available in Himalayas at a height from 1500 to 3000 meters. It is used for making pattern, manufacturing of doors, furniture, patterns, railway sleepers etc. It is a soft wood having a close grain structure unlikely to warp. It is easily workable and its cost is also low. It is preferred for making pattern for production of small size castings in small quantities.

Teak Wood

It is hard, very costly and available in golden yellow or dark brown color. Special stripes on it add to its beauty. In India, it is found in M.P. It is very strong and durable and has wide applications. It can maintain good polish. Besides making pattern, it is used for making good

quality furniture, plywood, ships etc. It is a straight-grained light wood. It is easily workable and has little tendency to warp. Its cost is moderate.

Mahogany

This is a hard and strong wood. Patterns made of this wood are more durable than those of above mentioned woods and they are less likely to warp. It has got a uniform straight grain structure and it can be easily fabricated in various shapes. It is costlier than teak and pine wood, It is generally not preferred for high accuracy for making complicated pattern. It is also preferred for production of small size castings in small quantities. The other Indian woods which may also be used for pattern making are deodar, walnllt, kail, maple, birch, cherry and shisham.

Advantages of wooden patterns

1 Wood can be easily worked.
2 It is light in weight.
3 It is easily available.
4 It is very cheap.
5 It is easy to join.
6 It is easy to obtain good surface finish.
7 Wooden laminated patterns are strong.
8 It can be easily repaired.

Disadvantages

1 It is susceptible to moisture.
2 It tends to warp.
3 It wears out quickly due to sand abrasion.
4 It is weaker than metallic patterns.

2. Metal

Metallic patterns are preferred when the number of castings required is large enough to justify their use. These patterns are not much affected by moisture as wooden pattern. The wear and tear of this pattern is very less and hence posses longer life. Moreover, metal is easier to shape the pattern with good precision, surface finish and intricacy in shapes. It can withstand against corrosion and handling for longer period. It possesses excellent strength to weight ratio. The main disadvantages of metallic patterns are higher cost, higher weight and tendency of rusting. It is preferred for production of castings in large quantities with same pattern. The metals commonly used for pattern making are cast iron, brass and bronzes and aluminum alloys.

Cast Iron

It is cheaper, stronger, tough, and durable and can produce a smooth surface finish. It also possesses good resistance to sand abrasion. The drawbacks of cast iron patterns are that they are hard, heavy, brittle and get rusted easily in presence of moisture.

Advantages

1. It is cheap
2. It is easy to file and fit

3. It is strong
4. It has good resistance against sand abrasion
5. Good surface finish

Disadvantages

1 It is heavy
2 It is brittle and hence it can be easily broken
3 It may rust

Brasses and Bronzes

These are heavier and expensive than cast iron and hence are preferred for manufacturing small castings. They possess good strength, machinability and resistance to corrosion and wear. They can produce a better surface finish. Brass and bronze pattern is finding application in making match plate pattern

Advantages

1. Better surface finish than cast iron.
2. Very thin sections can be easily casted.

Disadvantages

1. It is costly
2. It is heavier than cast iron.

Aluminum Alloys

Aluminum alloy patterns are more popular and best among all the metallic patterns because of their high light ness, good surface finish, low melting point and good strength. They also possesses good resistance to corrosion and abrasion by sand and there by enhancing longer life of pattern. These materials do not withstand against rough handling. These have poor repair ability and are preferred for making large castings.

Advantages

1. Aluminum alloys pattern does not rust.
2. They are easy to cast.
3. They are light in weight.
4. They can be easily machined.

Disadvantages

1. They can be damaged by sharp edges.
2. They are softer than brass and cast iron.
3. Their storing and transportation needs proper care.

White Metal (Alloy of Antimony, Copper and Lead)

Advantages

1. It is best material for lining and stripping plates.
2. It has low melting point around 260°C
3. It can be cast into narrow cavities.

Disadvantages

1. It is too soft.
2. Its storing and transportation needs proper care
3. It wears away by sand or sharp edges.

3. Plastic

Plastics are getting more popularity now a days because the patterns made of these materials are lighter, stronger, moisture and wear resistant, non sticky to molding sand, durable and they are not affected by the moisture of the molding sand. Moreover they impart very smooth surface finish on the pattern surface. These materials are somewhat fragile, less resistant to sudden loading and their section may need metal reinforcement. The plastics used for this purpose are thermosetting resins. Phenolic resin plastics are commonly used. These are originally in liquid form and get solidified when heated to a specified temperature. To prepare a plastic pattern, a mould in two halves is prepared in plaster of paris with the help of a wooden pattern known as a master pattern. The phenolic resin is poured into the mould and the mould is subjected to heat. The resin solidifies giving the plastic pattern. Recently a new material has stepped into the field of plastic which is known as foam plastic. Foam plastic is now being produced in several forms and the most common is the expandable polystyrene plastic category. It is made from benzene and ethyl benzene.

4. Plaster

This material belongs to gypsum family which can be easily cast and worked with wooden tools and preferable for producing highly intricate casting. The main advantages of plaster are that it has high compressive strength and is of high expansion setting type which compensate for the shrinkage allowance of the casting metal. Plaster of paris pattern can be prepared either by directly pouring the slurry of plaster and water in moulds prepared earlier from a master pattern or by sweeping it into desired shape or form by the sweep and strickle method. It is also preferred for production of small size intricate castings and making core boxes.

5. Wax

Patterns made from wax are excellent for investment casting process. The materials used are blends of several types of waxes, and other additives which act as polymerizing agents, stabilizers, etc. The commonly used waxes are paraffin wax, shellac wax, bees-wax, cerasin wax, and micro-crystalline wax. The properties desired in a good wax pattern include low ash content up to 0.05 per cent, resistant to the primary coat material used for investment, high tensile strength and hardness, and substantial weld strength. The general practice of making wax pattern is to inject liquid or semi-liquid wax into a split die. Solid injection is also used to avoid shrinkage and for better strength. Waxes use helps in imparting a high degree of surface finish and dimensional accuracy castings. Wax patterns are prepared by pouring heated wax into split moulds or a pair of dies. The dies after having been cooled down are parted off. Now the wax pattern is taken out and used for molding. Such patterns need not to be drawn out solid from the mould. After the mould is ready, the wax is poured out by heating the mould and keeping it upside down. Such patterns are generally used in the process of investment casting where accuracy is linked with intricacy of the cast object.

10.3 FACTORS EFFECTING SELECTION OF PATTERN MATERIAL

The following factors must be taken into consideration while selecting pattern materials.

1. Number of castings to be produced. Metal pattern are preferred when castings are required large in number.
2. Type of mould material used.
3. Kind of molding process.
4. Method of molding (hand or machine).
5. Degree of dimensional accuracy and surface finish required.
6. Minimum thickness required.
7. Shape, complexity and size of casting.
8. Cost of pattern and chances of repeat orders of the pattern

10.4 TYPES OF PATTERN

The types of the pattern and the description of each are given as under.

1. One piece or solid pattern
2. Two piece or split pattern
3. Cope and drag pattern
4. Three-piece or multi- piece pattern
5. Loose piece pattern
6. Match plate pattern
7. Follow board pattern
8. Gated pattern
9. Sweep pattern
10. Skeleton pattern
11. Segmental or part pattern

1. Single-piece or solid pattern

Solid pattern is made of single piece without joints, partings lines or loose pieces. It is the simplest form of the pattern. Typical single piece pattern is shown in Fig. 10.1.

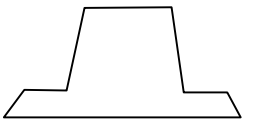


Fig. 10.1 Single piee pattern

2. Two-piece or split pattern

When solid pattern is difficult for withdrawal from the mold cavity, then solid pattern is splited in two parts. Split pattern is made in two pieces which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the withdrawal of the pattern. A typical example is shown in Fig. 10.2.

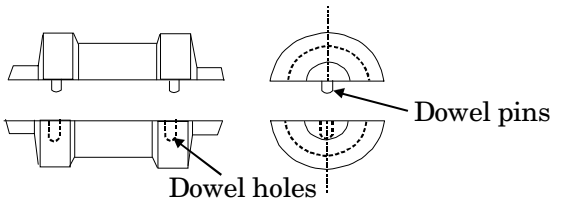


Fig. 10.2 Two piece pattern

3. Cope and drag pattern

In this case, cope and drag part of the mould are prepared separately. This is done when the complete mould is too heavy to be handled by one operator. The pattern is made up of two halves, which are mounted on different plates. A typical example of match plate pattern is shown in Fig. 10.3.

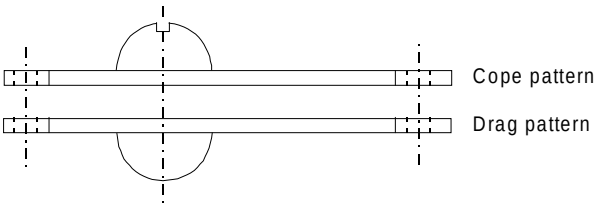


Fig. 10.3 Cope and drag pattern

4. Three-piece or multi-piece pattern

Some patterns are of complicated kind in shape and hence can not be made in one or two pieces because of difficulty in withdrawing the pattern. Therefore these patterns are made in either three pieces or in multi-pieces. Multi molding flasks are needed to make mold from these patterns.

5. Loose-piece Pattern

Loose piece pattern (Fig. 10.4) is used when pattern is difficult for withdrawl from the mould. Loose pieces are provided on the pattern and they are the part of pattern. The main pattern is removed first leaving the loose piece portion of the pattern in the mould. Finally the loose piece is withdrawal separately leaving the intricate mould.

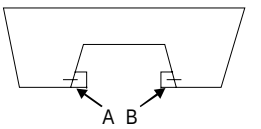


Fig. 10.4 Loose piece pattern

6. Match plate pattern

This pattern is made in two halves and is on mounted on the opposite sides of a wooden or metallic plate, known as match plate. The gates and runners are also attached to the plate. This pattern is used in machine molding. A typical example of match plate pattern is shown in Fig. 10.5.

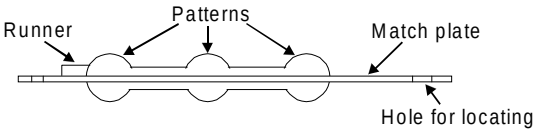


Fig. 10.5 Match plate pattern

7. Follow board pattern

When the use of solid or split patterns becomes difficult, a contour corresponding to the exact shape of one half of the pattern is made in a wooden board, which is called a follow board and it acts as a molding board for the first molding operation as shown in Fig. 10.6.

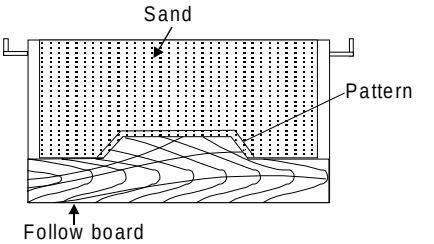


Fig. 10.6 Follow board pattern

8. Gated pattern

In the mass production of casings, multi cavity moulds are used. Such moulds are formed by joining a number of patterns and gates and providing a common runner for the molten metal, as shown in Fig. 10.7. These patterns are made of metals, and metallic pieces to form gates and runners are attached to the pattern.

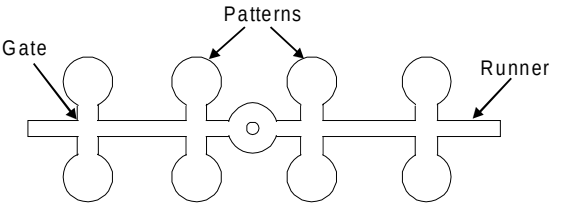


Fig. 10.7 Gated pattern

9. Sweep pattern

Sweep patterns are used for forming large circular moulds of symmetric kind by revolving a sweep attached to a spindle as shown in Fig. 10.8. Actually a sweep is a template of wood or metal and is attached to the spindle at one edge and the other edge has a contour depending upon the desired shape of the mould. The pivot end is attached to a stake of metal in the center of the mould.

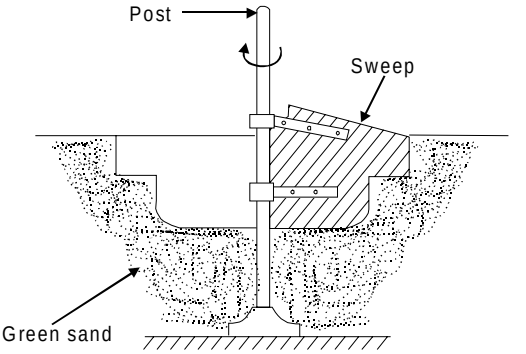


Fig. 10.8 Sweep pattern

10. Skeleton pattern

When only a small number of large and heavy castings are to be made, it is not economical to make a solid pattern. In such cases, however, a skeleton pattern may be used. This is a ribbed construction of wood which forms an outline of the pattern to be made. This frame work is filled with loam sand and rammed. The surplus sand is removed by strickle board. For round shapes, the pattern is made in two halves which are joined with glue or by means of screws etc. A typical skeleton pattern is shown in Fig. 10.9.

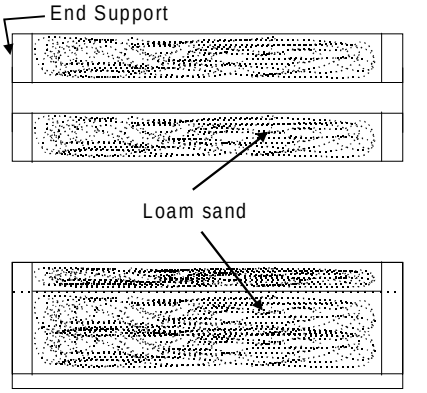


Fig. 10.9 Skeleton pattern

11. Segmental pattern

Patterns of this type are generally used for circular castings, for example wheel rim, gear blank etc. Such patterns are sections of a pattern so arranged as to form a complete mould by being moved to form each section of the mould. The movement of segmental pattern is guided by the use of a central pivot. A segment pattern for a wheel rim is shown in Fig. 10.10.

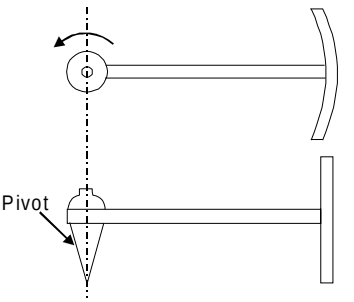


Fig. 10.10 Segmental or part pattern

10.5 PATTERN ALLOWANCES

Pattern may be made from wood or metal and its color may not be same as that of the casting. The material of the pattern is not necessarily same as that of the casting. Pattern carries an additional allowance to compensate for metal shrinkage. It carries additional allowance for machining. It carries the necessary draft to enable its easy removal from the sand mass. It carries distortions allowance also. Due to distortion allowance, the shape of casting is opposite to pattern. Pattern may carry additional projections, called core prints to produce seats or extra recess in mold for setting or adjustment or location for cores in mold cavity. It may be in pieces (more than one piece) whereas casting is in one piece. Sharp changes are not provided on the patterns. These are provided on the casting with the help of machining. Surface finish may not be same as that of casting.

The size of a pattern is never kept the same as that of the desired casting because of the fact that during cooling the casting is subjected to various effects and hence to compensate for these effects, corresponding allowances are given in the pattern. These various allowances given to pattern can be enumerated as, allowance for shrinkage, allowance for machining, allowance for draft, allowance for rapping or shake, allowance for distortion and allowance for mould wall movement. These allowances are discussed as under.

1. Shrinkage Allowance

In practice it is found that all common cast metals shrink a significant amount when they are cooled from the molten state. The total contraction in volume is divided into the following parts:

1. Liquid contraction, i.e. the contraction during the period in which the temperature of the liquid metal or alloy falls from the pouring temperature to the liquidus temperature.
2. Contraction on cooling from the liquidus to the solidus temperature, i.e. solidifying contraction.
3. Contraction that results there after until the temperature reaches the room temperature. This is known as solid contraction.

The first two of the above are taken care of by proper gating and risering. Only the last one, i.e. the solid contraction is taken care by the pattern makers by giving a positive shrinkage allowance. This contraction allowance is different for different metals. The contraction allowances for different metals and alloys such as Cast Iron 10 mm/mt.. Brass 16 mm/mt., Aluminium Alloys. 15 mm/mt., Steel 21 mm/mt., Lead 24 mm/mt. In fact, there is a special

rule known as the pattern marks contraction rule in which the shrinkage of the casting metals is added. It is similar in shape as that of a common rule but is slightly bigger than the latter depending upon the metal for which it is intended.

2. Machining Allowance

It is a positive allowance given to compensate for the amount of material that is lost in machining or finishing the casting. If this allowance is not given, the casting will become undersize after machining. The amount of this allowance depends on the size of casting, methods of machining and the degree of finish. In general, however, the value varies from 3 mm. to 18 mm.

3. Draft or Taper Allowance

Taper allowance (Fig. 10.11) is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier. The normal amount of taper on the external surfaces varies from 10 mm to 20 mm/mt. On interior holes and recesses which are smaller in size, the taper should be around 60 mm/mt. These values are greatly affected by the size of the pattern and the molding method. In machine molding its, value varies from 10 mm to 50 mm/mt.

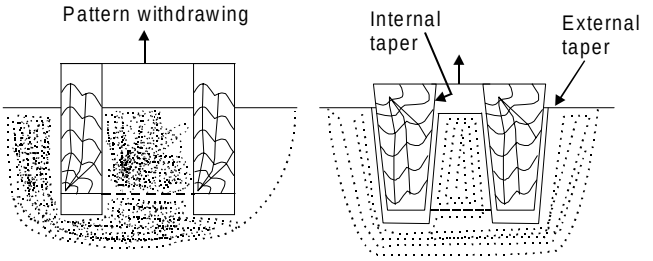


Fig. 10.11 Draft allowance

4. Rapping or Shake Allowance

Before withdrawing the pattern it is rapped and thereby the size of the mould cavity increases. Actually by rapping, the external sections move outwards increasing the size and internal sections move inwards decreasing the size. This movement may be insignificant in the case of small and medium size castings, but it is significant in the case of large castings. This allowance is kept negative and hence the pattern is made slightly smaller in dimensions 0.5-1.0 mm.

5. Distortion Allowance

This allowance is applied to the castings which have the tendency to distort during cooling due to thermal stresses developed. For example a casting in the form of U shape will contract at the closed end on cooling, while the open end will remain fixed in position. Therefore, to avoid the distortion, the legs of U pattern must converge slightly so that the sides will remain parallel after cooling.

6. Mold wall Movement Allowance

Mold wall movement in sand moulds occurs as a result of heat and static pressure on the surface layer of sand at the mold metal interface. In ferrous castings, it is also due to expansion due to graphitisation. This enlargement in the mold cavity depends upon the mold

density and mould composition. This effect becomes more pronounced with increase in moisture content and temperature.

10.6 CORE AND CORE BOX

Cores are compact mass of core sand that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting. The environment in which the core is placed is much different from that of the mold. In fact the core (Fig. 10.12) has to withstand the severe action of hot metal which completely surrounds it. Cores are classified according to shape and position in the mold. There are various types of cores such as horizontal core (Fig. 10.13), vertical core (Fig. 10.14), balanced core (Fig. 10.15), drop core (Fig. 10.16) and hanging core (Fig. 10.17).

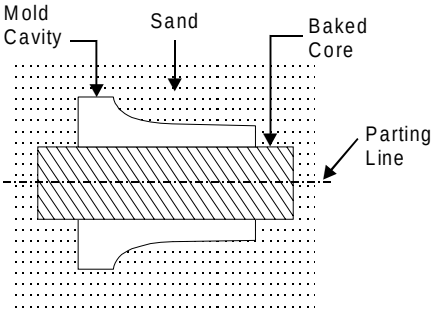


Fig. 10.12 Horizontal core

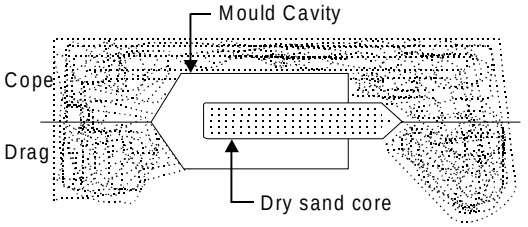


Fig. 10.13 Vertical core

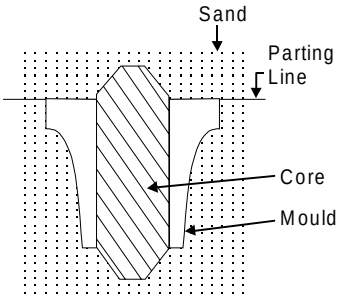


Fig. 10.14 Balanced core

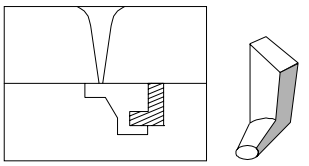


Fig. 10.15 Drop core

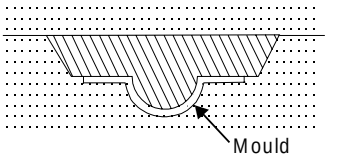


Fig. 10.16 Hanging core

There are various functions of cores which are given below

1. Core is used to produce hollowness in castings in form of internal cavities.
2. It may form a part of green sand mold

3. It may be deployed to improve mold surface.
4. It may provide external under cut features in casting.
5. It may be used to strengthen the mold.
6. It may be used to form gating system of large size mold
7. It may be inserted to achieve deep recesses in the casting

10.6.1 Core Box

Any kind of hollowness in form of holes and recesses in castings is obtained by the use of cores. Cores are made by means of core boxes comprising of either single or in two parts. Core boxes are generally made of wood or metal and are of several types. The main types of core box are half core box, dump core box, split core box, strickle core box, right and left hand core box and loose piece core box.

1. Half core box

This is the most common type of core box. The two identical halves of a symmetrical core prepared in the half core box are shown in Fig. 10.17. Two halves of cores are pasted or cemented together after baking to form a complete core.

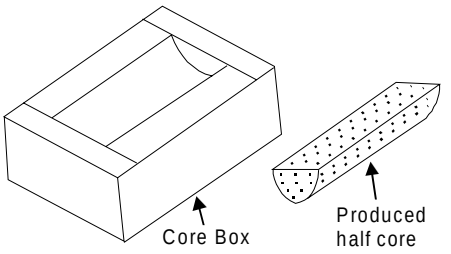


Fig. 10.17 Half core-box

2. Dump core box

Dump core box is similar in construction to half core box as shown in Fig. 10.18. The cores produced do not require pasting, rather they are complete by themselves. If the core produced is in the shape of a slab, then it is called as a slab box or a rectangular box. A dump core-box is used to prepare complete core in it. Generally cylindrical and rectangular cores are prepared in these boxes.

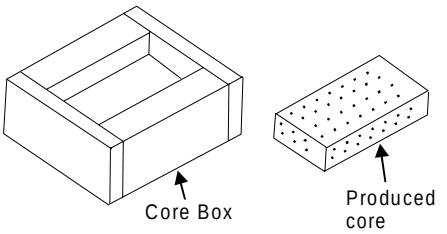


Fig. 10.18 Dump core-box

3. Split core box

Split core boxes are made in two parts as shown in Fig. 10.19. They form the complete core by only one ramming. The two parts of core boxes are held in position by means of clamps and their alignment is maintained by means of dowel pins and thus core is produced.

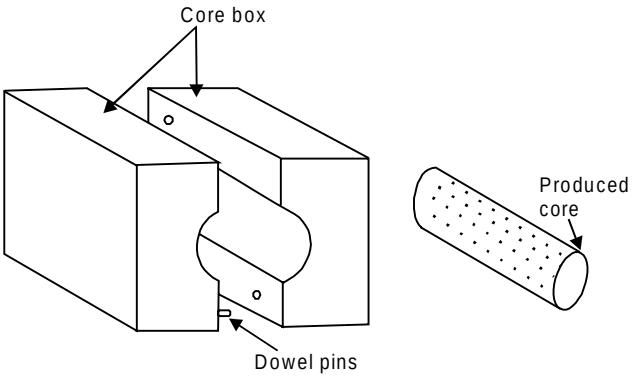


Fig. 10.19 Split core-box

4. Right and left hand core box

Some times the cores are not symmetrical about the center line. In such cases, right and left hand core boxes are used. The two halves of a core made in the same core box are not identical and they cannot be pasted together.

5. Strickle core box

This type of core box is used when a core with an irregular shape is desired. The required shape is achieved by striking oft the core sand from the top of the core box with a wooden piece, called as strickle board. The strickle board has the same contour as that of the required core.

6. Loose piece core box

Loose piece core boxes are highly suitable for making cores where provision for bosses, hubs etc. is required. In such cases, the loose pieces may be located by dowels, nails and dovetails etc. In certain cases, with the help of loose pieces, a single core box can be made to generate both halves of the right-left core.

10.7 CORE BOX ALLOWANCES

Materials used in making core generally swell and increase in size. This may lead to increase the size of core. The larger cores sometimes tend to become still larger. This increase in size may not be significant in small cores, but it is quite significant in large cores and therefore certain amount of allowance should be given on the core boxes to compensate for this increase the cores. It is not possible to lay down a rule for the amount of this allowance as this will depend upon the material used, but it is customary to give a negative allowance of 5 mm /mt.

10.8 COLOR CODIFICATION FOR PATTERNS AND CORE BOXES

There is no set or accepted standard for representing of various surfaces of pattern and core boxes by different colors. The practice of representing of various pattern surfaces by different colors varies with from country to country and sometimes with different manufactures within the country. Out of the various color codifications, the American practice is the most popular. In this practice, the color identification is as follows. Surfaces to be left unfinished after casting are to be painted as black. Surface to be machined are painted as red. Core

prints are painted as yellow. Seats for loose pieces are painted as red stripes on yellow background. Stop-offs is painted as black stripes on yellow base.

10.9 CORE PRINTS

When a hole blind or through is needed in the casting, a core is placed in the mould cavity to produce the same. The core has to be properly located or positioned in the mould cavity on pre-formed recesses or impressions in the sand. To form these recesses or impressions for generating seat for placement of core, extra projections are added on the pattern surface at proper places. These extra projections on the pattern (used for producing recesses in the mould for placement of cores at that location) are known as core prints. Core prints may be of horizontal, vertical, balanced, wing and core types. Horizontal core print produces seats for horizontal core in the mould. Vertical core print produces seats to support a vertical core in the mould. Balanced core print produces a single seat on one side of the mould and the core remains partly in this formed seat and partly in the mould cavity, the two portions balancing each other. The hanging portion of the core may be supported on chaplets. Wing core print is used to form a seat for a wing core. Cover core print forms seat to support a cover core.

10.10 WOODEN PATTERN AND WOODEN CORE BOX MAKING TOOLS

The job of patternmaker is basically done by a carpenter. The tools required for making patterns, therefore do not much differ from those used by a carpenter, excepting the special tools as per the needs of the trade. In addition to tools used by a carpenter, there is one more tool named as the contraction rule, which is a measuring tool of the patternmaker's trade. All castings shrinks during cooling from the molten state, and patterns have to be made correspondingly larger than the required casting in order to compensate for the loss in size due to this shrinkage. Various metals and alloys have various shrinkages. The allowance for shrinkage, therefore, varies with various metals and also according to particular casting conditions, and hence the size of the pattern is proportionally increased. A separate scale is available for each allowance, and it enables the dimensions to be set out directly during laying out of the patterns. The rule usually employed the one that has two scales on each side, the total number of scales being four for four commonly cast metals namely, steel, cast iron, brass and aluminum. To compensate for contraction or shrinkage, the graduations are oversized by a proportionate amount, e.g. on 1 mm or 1 per cent scale each 100 cm is longer by 1 cm. The general tools and equipment used in the pattern making shop are given as under.

1. Measuring and Layout Tools

1. Wooden or steel scale or rule
2. Dividers
3. Calipers
4. Try square
5. Caliper rule
6. Flexible rule
7. Marking gauge
8. T-bevel
9. Combination square

2. Sawing Tools

1. Compass saw
2. Rip saw
3. Coping saw
4. Dovetail saw

5. Back saw
6. Panel saw
7. Miter saw

3. Planning Tools

1. Jack plane
2. Circular plane
3. Router plane
4. Rabbet plane
5. Block plane
6. Bench plane
7. Core box plane

4. Boring Tools

1. Hand operated drills
2. Machine operated drills
3. Twist drill
4. Countersunk
5. Brace
6. Auger bit
7. Bit gauge

5. Clamping Tools

1. Bench vice
2. C-clamp
3. Bar clamp
4. Hand screw
5. Pattern maker's vice
6. Pinch dog

6. Miscellaneous Tools

1. Screw Driver
2. Vaious types of hammers
3. Chisel
4. Rasp
5. File
6. Nail set
7. Screw driver
8. Bradawl
9. Brad pusher
10. Cornering tool

10.11 WOODEN PATTERN AND WOODEN CORE BOX MAKING MACHINES

Modern wooden pattern and wooden core making shop requires various wood working machines for quick and mass production of patterns and core boxes. Some of the commonly machines used in making patterns and coreboxes of various kinds of wood are discussed as under.

1. **Wood Turning Lathe.** Patterns for cylindrical castings are made by this lathe.
2. **Abrasive Disc Machine.** It is used for shaping or finishing flat surfaces on small pieces of wood.
3. **Abrasive Belt Machine.** It makes use of an endless abrasive belt. It is used in shaping the patterns.
4. **Circular Saw.** It is used for ripping, cross cutting, beveling and grooving.
5. **Band Saw.** It is designed to cut wood by means of an endless metal saw band.
6. **Jig or Scroll Saw.** It is used for making intricate irregular cuts on small work.
7. **Jointer.** The jointer planes the wood by the action of the revolving cutter head.

8. **Drill Press.** It is used for drilling, boring, mortising, shaping etc.
9. **Grinder.** It is used for shaping and sharpening the tools.
10. **Wood Trimmer.** It is used for mitering the moldings accurately.
11. **Wood Shaper.** It is used for imparting the different shapes to the wood.
12. **Wood Planer.** Its purpose is similar to jointer but it is specially designed for planning larger size.
13. **Tennoner.** These are used for sawing (accurate shape and size).
14. **Mortiser.** It is used to facilitate the cutting of mortise and tenon.

10.12 DESIGN CONSIDERATIONS IN PATTERN MAKING

The following considerations should always be kept in mind while designing a pattern.

1. All Abrupt changes in section of the pattern should be avoided as far as possible.
2. Parting line should be selected carefully, so as to allow as small portion of the pattern as far as possible in the cope area
3. The thickness and section of the pattern should be kept as uniform as possible.
4. Sharp corners and edges should be supported by suitable fillets or otherwise rounded of. It will facilitate easy withdrawal of pattern, smooth flow of molten metal and ensure a sound casting.
5. Surfaces of the casting which are specifically required to be perfectly sound and clean should be so designed that they will be molded in the drag because the possible defects due to loose sand and inclusions will occur in the cope.
6. As far as possible, full cores should be used instead of cemented half cores for reducing cost and for accuracy.
7. For mass production, the use of several patterns in a mould with common riser is to be preferred.
8. The pattern should have very good surface finish as it directly affects the corresponding finish of the casting.
9. Shape and size of the casting and that of the core should be carefully considered to decide the size and location of the core prints.
10. Proper material should always be selected for the pattern after carefully analyzing the factors responsible for their selection.
11. Try to employ full cores always instead of jointed half cores as far as possible. This will reduce cost and ensure greater dimensional accuracy.
12. The use of offset parting, instead of cores as for as possible should be encouraged to the great extent.
13. For large scale production of small castings, the use of gated or match- plate patterns should be preferred wherever the existing facilities permit.
14. If gates, runners and risers are required to be attached with the pattern, they should be properly located and their sudden variation in dimensions should be avoided.
15. Wherever there is a sharp corner, a fillet should be provided, and the corners may be rounded up for easy withdrawal of patterns as well as easy flow of molten metal in the mould.

16. Proper allowances should be provided, wherever necessary.
17. As for as possible, the pattern should have a good surface finish because the surface finish of the casting depends totally on the surface finish of the pattern and the kind of facing of the mold cavity.

10.13 PATTERN LAYOUT

After deciding the molding method and form of pattern, planning for the development of complete pattern is made which may be in two different stages. The first stage is to prepare a layout of the different parts of the pattern. The next stage is to shape them. The layout preparation consists of measuring, marking, and setting out the dimensions on a layout board including needed allowances. The first step in laying out is to study the working drawing carefully and select a suitable board of wood that can accommodate at least two views of the same on full size scale. The next step is to decide a working face of the board and plane an adjacent edge smooth and square with the said face. Select a proper contraction scale for measuring and marking dimensions according to the material of the casting. Further the layout is prepared properly and neatly using different measuring and making tools specifying the locations of core prints and machined surfaces. Finally on completion of the layout, check carefully the dimension and other requirements by incorporating all necessary pattern allowances before starting construction of the pattern.

10.14 PATTERN CONSTRUCTION

On preparing the pattern layout, the construction for making it is started by studying the layout and deciding the location of parting surfaces. From the layout, try to visualize the shape of the pattern and determine the number of separate pieces to be made and the process to be employed for making them. Then the main part of pattern body is first constructed using pattern making tools. The direction of wood grains is kept along the length of pattern as far as possible to ensure due strength and accuracy. Further cut and shape the other different parts of pattern providing adequate draft on them. The prepared parts are then checked by placing them over the prepared layout. Further the different parts of the pattern are assembled with the main body in proper position by gluing or by means of dowels as the case may be. Next the relative locations of all the assembled parts on the pattern are adjusted carefully. Then, the completed pattern is checked for accuracy. Next all the rough surfaces of pattern are finished and imparted with a thin coating of shellac varnish. The wax or leather fillets are then fitted wherever necessary. Wooden fillets should also be fitted before sanding and finishing. The pattern surface once again prepared for good surface and give final coat of shellac. Finally different parts or surfaces of pattern are colored with specific colors mixed in shellac or by painting as per coloring specifications.

10.15 QUESTIONS

1. Define pattern? What is the difference between pattern and casting?
2. What is Pattern? How does it differ from the actual product to be made from it.?
3. What important considerations a pattern-maker has to make before planning a pattern?
4. What are the common allowances provided on patterns and why?
5. What are the factors which govern the selection of a proper material for pattern- making?

6. What are master patterns? How does their size differ from other patterns? Explain.
7. Discuss the utility of unserviceable parts as patterns.
8. What are the allowances provided to the patterns?
9. Discuss the various positive and negative allowances provided to the patterns.
10. Discuss briefly the match plate pattern with the help of suitable sketch. ?
11. Where skeleton patterns are used and what is the advantage?
12. Sketch and describe the use and advantages of a gated pattern?
13. Give common materials used for pattern making? Discuss their merits and demerits?
14. Write short notes on the following:
    (*i*) Contraction scale, (*ii*) Uses of fillets on patterns, and
    (*iii*) Pattern with loose pieces (*iv*) Uses of cores
15. Discus briefly the various types of patterns used in foundry shop?
16. Define the following?

(*a*) Core prints
(*b*) Mould or cavity
(*c*) Core boxes
(*d*) Shrinkage allowance
(*e*) Chaplets
(*f*) Chills

17. Discuss briefly the various functions of a pattern?
18. Write the color coding for patterns and core boxes?

11
CHAPTER

FOUNDRY TOOLS AND EQUIPMENTS

11.1 INTRODUCTION

There are large number of tools and equipments used in foundry shop for carrying out different operations such as sand preparation, molding, melting, pouring and casting. They can be broadly classified as hand tools, sand conditioning tool, flasks, power operated equipments, metal melting equipments and fettling and finishing equipments. Different kinds of hand tools are used by molder in mold making operations. Sand conditioning tools are basically used for preparing the various types of molding sands and core sand. Flasks are commonly used for preparing sand moulds and keeping molten metal and also for handling the same from place to place. Power operated equipments are used for mechanizing processes in foundries. They include various types of molding machines, power riddles, sand mixers and conveyors, grinders etc. Metal melting equipment includes various types of melting furnaces such as cupola, pit furnace, crucible furnaces etc. Fettling and finishing equipments are also used in foundry work for cleaning and finishing the casting. General tools and equipment used in foundry are discussed as under.

11.2 HAND TOOLS USED IN FOUNDRY SHOP

The common hand tools used in foundry shop are fairly numerous. A brief description of the following foundry tools (Fig. 11.1) used frequently by molder is given as under.

Hand riddle

Hand riddle is shown in Fig. 11.1(a). It consists of a screen of standard circular wire mesh equipped with circular wooden frame. It is generally used for cleaning the sand for removing foreign material such as nails, shot metal, splinters of wood etc. from it. Even power operated riddles are available for riddling large volume of sand.

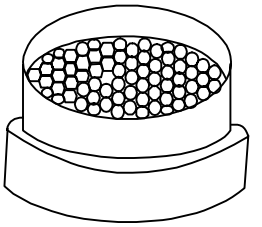


Fig. 11.1 (a)

Shovel

Shovel is shown in Fig. 11.1(b). It consists of an steel pan fitted with a long wooden handle. It is used in mixing, tempering and conditioning the foundry sand by hand. It is also used for moving and transforming the molding sand to the container and molding box or flask. It should always be kept clean.

Rammers

Rammers are shown in Fig. 11.1(c). These are required for striking the molding sand mass in the molding box to pack or compact it uniformly all around the pattern. The common forms of rammers used in ramming are hand rammer, peen rammer, floor rammer and pneumatic rammer which are briefly described as

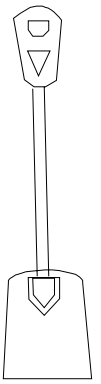


Fig. 11.1 (b)

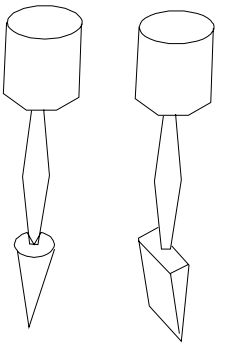


Fig. 11.1 (c)

(*i*) Hand rammer

It is generally made of wood or metal. It is small and one end of which carries a wedge type construction, called peen and the other end possesses a solid cylindrical shape known as butt. It is used for ramming the sand in bench molding work.

(*ii*) Peen rammer

It has a wedge-shaped construction formed at the bottom of a metallic rod. It is generally used in packing the molding sand in pockets and comers.

(*iii*) Floor rammer

It consists of a long steel bar carrying a peen at one end and a flat portion on the other. It is a heavier and larger in comparison to hand rammer. Its specific use is in floor molding for ramming the sand for larger molds. Due to its large length, the molder can operate it in standing position.

(*iv*) Pneumatic rammers

They save considerable time and labor and are used for making large molds.

Sprue pin

Sprue pin is shown in Fig. 11.1(d). It is a tapered rod of wood or iron which is placed or pushed in cope to join mold cavity while the molding sand in the cope is being rammed. Later its withdrawal from cope produce a vertical hole in molding sand, called sprue through which the molten metal is poured into the mould using gating system. It helps to make a passage for pouring molten metal in mold through gating system

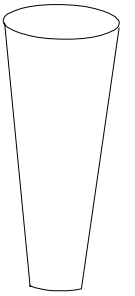


Fig. 11.1 (d)

Strike off bar

Strike off bar (Fig. 11.1(e)) is a flat bar having straight edge and is made of wood or iron. It is used to strike off or remove the excess sand from the top of a molding box after completion of ramming thereby making its surface plane and smooth. Its one edge is made beveled and the other end is kept perfectly smooth and plane.

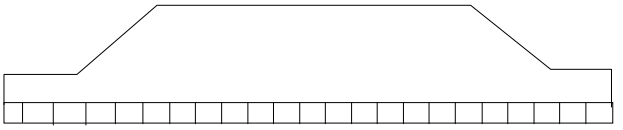


Fig. 11.1 (e)

Mallet

Mallet is similar to a wooden hammer and is generally as used in carpentry or sheet metal shops. In molding shop, it is used for driving the draw spike into the pattern and then rapping it for separation from the mould surfaces so that pattern can be easily withdrawn leaving the mold cavity without damaging the mold surfaces.

Draw spike

Draw spike is shown Fig. 11.1(f). It is a tapered steel rod having a loop or ring at its one end and a sharp point at the other. It may have screw threads on the end to engage metal pattern for it withdrawal from the mold. It is used for driven into pattern which is embedded in the molding sand and raps the pattern to get separated from the pattern and finally draws out it from the mold cavity.

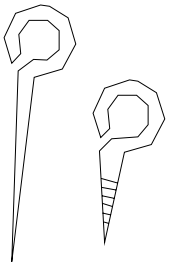


Fig. 11.1 (f)

Fig. 11.1 (g)

Vent rod

Vent rod is shown in Fig. 11.1(g). It is a thin spiked steel rod or wire carrying a pointed edge at one end and a wooden handle or a bent loop at the other. After ramming and striking off the excess sand it is utilized to pierce series of small holes in the molding sand in the cope portion. The series of pierced small holes are called vents holes which allow the exit or escape of steam and gases during pouring mold and solidifying of the molten metal for getting a sound casting.

Lifters

Lifters are shown in Fig. 11.1(h, i, j and k). They are also known as cleaners or finishing tool which are made of thin sections of steel of various length and width with one end bent

at right angle. They are used for cleaning, repairing and finishing the bottom and sides of deep and narrow openings in mold cavity after withdrawal of pattern. They are also used for removing loose sand from mold cavity.

Fig. 11.1 (h)

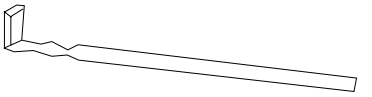


Fig. 11.1 (i)

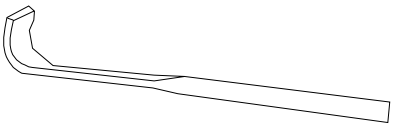


Fig. 11.1 (j)

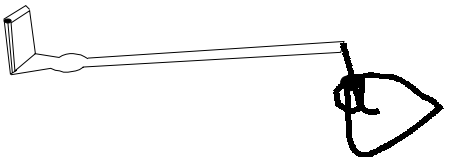


Fig. 11.1 (k)

Trowels

Trowels are shown in Fig. 11.1(l, m and n). They are utilized for finishing flat surfaces and joints and partings lines of the mold. They consist of metal blade made of iron and are equipped with a wooden handle. The common metal blade shapes of trowels may be pointed or contoured or rectangular oriented. The trowels are basically employed for smoothing or slicking the surfaces of molds. They may also be used to cut in-gates and repair the mold surfaces.

Fig. 11.1 (l)

Fig. 11.1 (m)

Fig. 11.1 (n)

Slicks

Slicks are shown in Fig. 11.1(o, p, q, and r). They are also recognized as small double ended mold finishing tool which are generally used for repairing and finishing the mold surfaces and their edges after withdrawal of the pattern. The commonly used slicks are of the types of heart and leaf, square and heart, spoon and bead and heart and spoon. The nomenclatures of the slicks are largely due to their shapes.

Fig. 11.1 (o)

Fig. 11.1 (p)

Fig. 11.1 (q)

Fig. 11.1 (r)

Smoothers

Smothers are shown in Fig. 11.1(s and t). According to their use and shape they are given different names. They are also known as finishing tools which are commonly used for repairing and finishing flat and round surfaces, round or square corners and edges of molds.

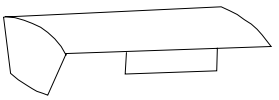


Fig. 11.1 (s)

Fig. 11.1 (t)

Swab

Swab is shown in Fig. 11.1(u). It is a small hemp fiber brush used for moistening the edges of sand mould, which are in contact with the pattern surface before withdrawing the pattern. It is used for sweeping away the molding sand from the mold surface and pattern. It is also used for coating the liquid blacking on the mold faces in dry sand molds.

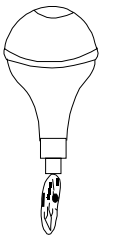


Fig. 11.1 (u)

Spirit level

Spirit level is used by molder to check whether the sand bed or molding box is horizontal or not.

Gate cutter

Gate cutter (Fig. 11.1(v)) is a small shaped piece of sheet metal commonly used to cut runners and feeding gates for connecting sprue hole with the mold cavity.

Fig. 11.1 (v)

Gaggers

Gaggers are pieces of wires or rods bent at one or both ends which are used for reinforcing the downward projecting sand mass in the cope are known as gaggers. They support hanging

bodies of sand. They possess a length varying from 2 to 50 cm. A gagger is always used in cope area and it may reach up to 6 mm away from the pattern. It should be coated with clay wash so that the sand adheres to it. Its surface should be rough in order to have a good grip with the molding sand. It is made up of steel reinforcing bar.

Spray-gun

Spray gun is mainly used to spray coating of facing materials etc. on a mold or core surface.

Nails and wire pieces

They are basically used to reinforce thin projections of sand in the mold or cores.

Wire pieces, spring and nails

They are commonly used to reinforce thin projections of sand in molds or cores. They are also used to fasten cores in molds and reinforce sand in front of an in-gate.

Bellows

Bellows gun is shown in Fig. 11.1(w). It is hand operated leather made device equipped with compressed air jet to blow or pump air when operated. It is used to blow away the loose or unwanted sand from the surfaces of mold cavities.

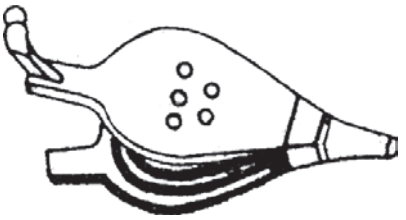


Fig. 11.1 (w)

Fig. 11.1 (a–w) Common hand tools used in foundry

Clamps, cotters and wedges

They are made of steel and are used for clamping the molding boxes firmly together during pouring.

11.3 FLASKS

The common flasks are also called as containers which are used in foundry shop as mold boxes, crucibles and ladles.

1. Moulding Boxes

Mold boxes are also known as molding flasks. Boxes used in sand molding are of two types:

(*a*) Open molding boxes. Open molding boxes are shown in Fig. 11.2. They are made with the hinge at one corner and a lock on the opposite corner. They are also known as snap molding boxes which are generally used for making sand molds. A snap molding is made of wood and is hinged at one corner. It has special applications in bench molding in green sand work for small nonferrous castings. The mold is first made in the snap flask and then it is

removed and replaced by a steel jacket. Thus, a number of molds can be prepared using the same set of boxes. As an alternative to the wooden snap boxes the cast-aluminum tapered closed boxes are finding favor in modern foundries. They carry a tapered inside surface which is accurately ground and finished. A solid structure of this box gives more rigidity and strength than the open type. These boxes are also removed after assembling the mould. Large molding boxes are equipped with reinforcing cross bars and ribs to hold the heavy mass of sand and support gaggers. The size, material and construction of the molding box depend upon the size of the casting.

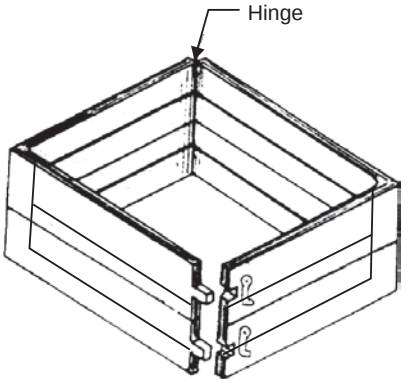


Fig. 11.2 Open molding box

(*b*) Closed molding boxes. Closed molding boxes are shown in Fig. 11.3 which may be made of wood, cast-iron or steel and consist of two or more parts. The lower part is called the drag, the upper part the cope and all the intermediate parts, if used, cheeks. All the parts are individually equipped with suitable means for clamping arrangements during pouring. Wooden Boxes are generally used in green-sand molding. Dry sand moulds always require metallic boxes because they are heated for drying. Large and heavy boxes are made from cast iron or steel and carry handles and grips as they are manipulated by cranes or hoists, etc. Closed metallic molding boxes may be called as a closed rectangular molding box (Fig. 11.3) or a closed round molding box (Fig. 11.4).

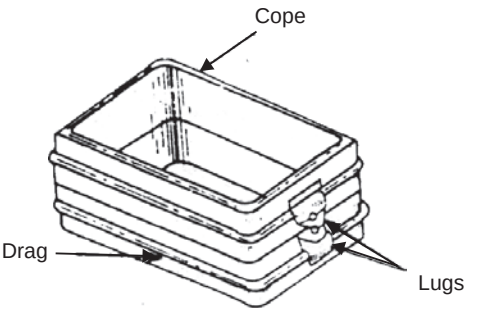


Fig. 11.3 Closed rectangular molding box

2. Crucible

Crucibles are made from graphite or steel shell lined with suitable refractory material like fire clay. They are commonly named as metal melting pots. The raw material or charge is broken into small pieces and placed in them. They are then placed in pit furnaces which are coke-fired. In oil- fired tilting furnaces, they form an integral part of the furnace itself and the charge is put into them while they are in position. After melting of metals in crucibles, they are taken out and received in crucible handle. Pouring of molten is generally done directly by them instead of transferring the molten metal to ladles. But in the case of an oil-fired furnace, the molten metal is first received in a ladle and then poured into the molds.

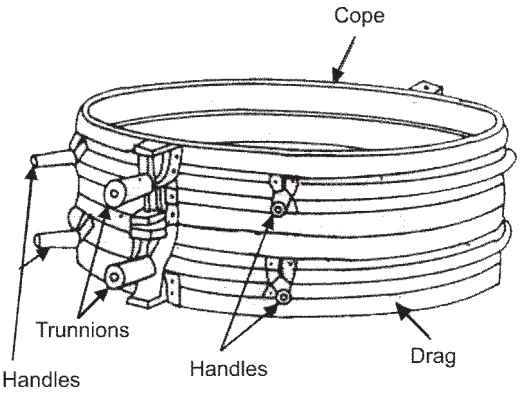


Fig. 11.4 Closed round molding box

3. Ladle

It is similar in shape to the crucible which is also made from graphite or steel shell lined with suitable refractory material like fire clay. It is commonly used to receive molten metal from the melting furnace and pour the same into the mold cavity. Its size is designated by its capacity. Small hand shank ladles are used by a single foundry personal and are provided with only one handle. It may be available in different capacities up to 20 kg. Medium and large size ladles are provided with handles on both sides to be handled by two foundry personals. They are available in various sizes with their capacity varying from 30 kg to 150 kg. Extremely large sizes, with capacities ranging from 250 kg to 1000 kg, are found in crane ladles. Geared crane ladles can hold even more than 1000 kg of molten metal. The handling of ladles can be mechanized for good pouring control and ensuring better safety for foundry personals workers. All the ladles consist of an outer casing made of steel or plate bent in proper shape and then welded. Inside this casing, a refractory lining is provided. At its top, the casing is shaped to have a controlled and well directed flow of molten metal. They are commonly used to transport molten metal from furnace to mold

11.4 POWER OPERATED EQUIPMENTS

Power operated foundry equipments generally used in foundries are different types of molding machines and sand slingers, core making, core baking equipment, power riddles, mechanical conveyors, sand mixers, material handling equipment and sand aerators etc. Few commonly used types of such equipments are discussed as under.

11.4.1 Moulding Machines

Molding machine acts as a device by means of a large number of co-related parts and mechanisms, transmits and directs various forces and motions in required directions so as to help the preparation of a sand mould. The major functions of molding machines involves ramming of molding sand, rolling over or inverting the mould, rapping the pattern and withdrawing the pattern from the mould. Most of the molding machines perform a combination of two or more of functions. However, ramming of sand is the basic function of most of these machines. Use of molding machine is advisable when large number of repetitive castings is to be produced as hand molding may be tedious, time consuming, laborious and expensive comparatively.

11.4.2 Classification of Moulding Machines

The large variety of molding machines that are available in different designs which can be classified as squeezer machine, jolt machine, jolt-squeezer machine, slinging machines, pattern draw machines and roll over machines. These varieties of machines are discussed as under.

11.4.2.1 Squeezer machine

These machines may be hand operated or power operated. The pattern is placed over the machine table, followed by the molding box. In hand-operated machines, the platen is lifted by hand operated mechanism. In power machines, it is lifted by the air pressure on a piston in the cylinder in the same way as in jolt machine. The table is raised gradually. The sand in the molding box is squeezed between plate and the upward rising table thus enabling a uniform pressing of sand in the molding box. The main advantage of power operated machines in comparison hand operated machines is that more pressure can be applied in power operated.

11.4.2.2 Jolt machine

This machine is also known as jar machine which comprises of air operated piston and cylinder. The air is allowed to enter from the bottom side of the cylinder and acts on the bottom face of the piston to raise it up. The platen or table of the machine is attached at the top of the piston which carries the pattern and molding box with sand filled in it. The upward movement of piston raises the table to a certain height and the air below the piston is suddenly released, resulting in uniform packing of sand around the pattern in the molding box. This process is repeated several times rapidly. This operation is known as jolting technique.

11.4.2.3 Jolt-squeezer machine

It uses the principle of both jolt and squeezer machines in which complete mould is prepared. The cope, match plate and drag are assembled on the machine table in a reverse position, that is, the drag on the top and the cope below. Initially the drag is filled with sand followed by ramming by the jolting action of the table. After leveling off the sand on the upper surface, the assembly is turned upside down and placed over a bottom board placed on the table. Next, the cope is filled up with sand and is rammed by squeezing between the overhead plate and the machine table. The overhead plate is then swung aside and sand on the top leveled off, cope is next removed and the drag is vibrated by air vibrator. This is followed by removal of match plate and closing of two halves of the mold for pouring the molten metal. This machine is used to overcome the drawbacks of both squeeze and jolt principles of ramming molding sand.

11.4.2.4 Slinging machines

These machines are also known as sand slingers and are used for filling and uniform ramming of molding sand in molds. In the slinging operations, the consolidation and ramming are obtained by impact of sand which falls at a very high velocity on pattern. These machines are generally preferred for quick preparation of large sand moulds. These machines can also be used in combination with other devices such as, roll over machines and pattern draw machines for reducing manual operations to minimum. These machines can be stationary and portable types. Stationary machines are used for mass production in bigger foundries whereas portable type machines are mounted on wheels and travel in the foundry shop on a well planned fixed path. A typical sand slinger consists of a heavy base, a bin or hopper to carry sand, a bucket elevator to which are attached a number of buckets and a swinging arm which

carries a belt conveyor and the sand impeller head. Well prepared sand is filed in a bin through the bottom of which it is fed to the elevator buckets. These buckets discharge the molding sand to the belt conveyor which conveys the same to the impeller head. This head can be moved at any location on the mold by swinging the arm. The head revolves at a very high speed and, in doing so, throws stream of molding sand into the molding box at a high velocity. This process is known as slinging. The force of sand ejection and striking into the molding box compel the sand gets packed in the box flask uniformly. This way the satisfactory ramming is automatically get competed on the mold. It is a very useful machine in large foundries.

11.4.2.5 Pattern draw machines

These machines enable easy withdrawal of patterns from the molds. They can be of the kind of stripping plate type and pin lift or push off type. Stripping plate type of pattern draw machines consists of a stationary platen or table on which is mounted a stripping plate which carries a hole in it. The size and shape of this hole is such that it fits accurately around the pattern. The pattern is secured to a pattern plate and the latter to the supporting ram. The pattern is drawn through the stripping plate either by raising the stripping plate and the mould up and keeping the pattern stationary or by keeping the stripping plate and mould stationary and moving the pattern supporting ram downwards along with the pattern and pattern plate. A suitable mechanism can be incorporated in the machine for these movements.

11.4.2.6 Roll-over machine

This machine comprises of a rigid frame carrying two vertical supports on its two sides having bearing supports of trunnions on which the roll-over frame of the machine is mounted. The pattern is mounted on a plate which is secured to the roll-over frame. The platen of the machine can be moved up and down. For preparation of the mould, the roll-over frame is clamped in position with the pattern facing upward. Molding box is placed over the pattern plate and clamped properly. Molding sand is then filled in it and rammed by hand and the extra molding sand is struck off and molding board placed over the box and clamped to it. After that the roll-over frame is unclamped and rolled over through 180° to suspend the box below the frame. The platen is then lifted up to butt against the suspending box. The box is unclamped from the pattern plate to rest over the platen which is brought down leaving the pattern attached to the plate. The prepared mold is now lowered. The frame is then again rolled over to the original position for ramming another flask. Other mechanisms are always incorporated to enable the above rolling over and platen motion. Some roll-over machines may carry a pneumatic mechanism for rolling over. There are others mechanism also which incorporate a jolting table for ramming the sand and an air operated rocking arm to facilitate rolling over. Some machines incorporate a mechanically or pneumatically operated squeezing mechanism for sand ramming in addition to the air operated rolling over mechanism. All such machines are frequently referred to as combination machines to carry out the molding tasks automatically.

11.5 QUESTIONS

1. How do you classify the different tools and equipment used in foundries?
2. Name the different tools used in hand molding stating their use.
3. Sketch and describe the different types of molding boxes you know.
4. What are ladles and crucibles? How do they differ from each other?

5. Describe the working principles and uses of different molding machines.

6. Describe, with the help of sketches, how a mould is rammed on a diaphragm molding machine.

7. What is a molding machine? What main functions does it perform?

8. Describe the principle of working of different pattern draw machines.

9. Describe the principle of working of a rollover machine.

10. What is sand slinger and how does it differ from other molding machines?

12
CHAPTER

MOLD AND CORE MAKING

12.1 INTRODUCTION

A suitable and workable material possessing high refractoriness in nature can be used for mould making. Thus, the mold making material can be metallic or non-metallic. For metallic category, the common materials are cast iron, mild steel and alloy steels. In the non-metallic group molding sands, plaster of paris, graphite, silicon carbide and ceramics are included. But, out of all, the molding sand is the most common utilized non-metallic molding material because of its certain inherent properties namely refractoriness, chemical and thermal stability at higher temperature, high permeability and workability along with good strength. Moreover, it is also highly cheap and easily available. This chapter discusses molding and core sand, the constituents, properties, testing and conditioning of molding and core sands, procedure for making molds and cores, mold and core terminology and different methods of molding.

12.2 MOLDING SAND

The general sources of receiving molding sands are the beds of sea, rivers, lakes, granulular elements of rocks, and deserts. The common sources of molding sands available in India are as follows:

1 Batala sand (Punjab)
2 Ganges sand (Uttar Pradesh)
3 Oyaria sand (Bihar)
4 Damodar and Barakar sands (Bengal- Bihar Border)
5 Londha sand (Bombay)
6 Gigatamannu sand (Andhra Pradesh) and
7 Avadi and Veeriyambakam sand (Madras)

Molding sands may be of two types namely natural or synthetic. Natural molding sands contain sufficient binder. Whereas synthetic molding sands are prepared artificially using basic sand molding constituents (silica sand in 88-92%, binder 6-12%, water or moisture content 3-6%) and other additives in proper proportion by weight with perfect mixing and mulling in suitable equipments.

12.3 CONSTITUENTS OF MOLDING SAND

The main constituents of molding sand involve silica sand, binder, moisture content and additives.

12.3.1 Silica sand

Silica sand in form of granular quarts is the main constituent of molding sand having enough refractoriness which can impart strength, stability and permeability to molding and core sand. But along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities. The chemical composition of silica sand gives an idea of the impurities like lime, magnesia, alkalis etc. present. The presence of excessive amounts of iron oxide, alkali oxides and lime can lower the fusion point to a considerable extent which is undesirable. The silica sand can be specified according to the size (small, medium and large silica sand grain) and the shape (angular, sub-angular and rounded).

12.3.1.1 Effect of grain shape and size of silica sand

The shape and size of sand grains has a significant effect on the different properties of molding and core sands. The shape of the sand grains in the mold or core sand determines the possibility of its application in various types of foundry practice. The shape of foundry sand grains varies from round to angular. Some sands consist almost entirely of grains of one shape, whereas others have a mixture of various shapes. According to shape, foundry sands are classified as rounded, sub-angular, angular and compound. Use of angular grains (obtained during crushing of rocks hard sand stones) is avoided as these grains have a large surface area. Molding sands composed of angular grains will need higher amount of binder and moisture content for the greater specific surface area of sand grain. However, a higher percentage of binder is required to bring in the desired strength in the molding sand and core sand. For good molding purposes, a smooth surfaced sand grains are preferred. The smooth surfaced grain has a higher sinter point, and the smooth surface secures a mixture of greater permeability and plasticity while requiring a higher percentage of blind material. Rounded shape silica sand grain sands are best suited for making permeable molding sand. These grains contribute to higher bond strength in comparison to angular grain. However, rounded silica sand grains sands have higher thermal expandability than angular silica grain sands. Silica sand with rounded silica sand grains gives much better compactability under the same conditions than the sands with angular silica grains. This is connected with the fact that the silica sand with rounded grains having the greatest degree of close packing of particles while sand with angular grains the worst. The green strength increases as the grains become more rounded. On the other hand, the grade of compactability of silica sands with rounded sand grains is higher, and other, the contact surfaces between the individual grains are greater on rounded grains than on angular grains. As already mentioned above, the compactability increases with rounded grains. The permeability or porosity property of molding sand and core sand therefore, should increase with rounded grains and decrease with angular grains. Thus the round silica sand grain size greatly influences the properties of molding sand.

The characteristics of sub-angular sand grains lie in between the characteristics of sand grains of angular and rounded kind. Compound grains are cemented together such that they fail to get separated when screened through a sieve. They may consist of round, sub-angular, or angular sub-angular sand grains. Compound grains require higher amounts of binder and moisture content also. These grains are least desirable in sand mixtures because they have a tendency to disintegrate at high temperatures. Moreover the compound grains are cemented together and they fail to separate when screened.

Grain sizes and their distribution in molding sand influence greatly the properties of the sand. The size and shape of the silica sand grains have a large bearing upon its strength and other general characteristics. The sand with wide range of particle size has higher compactability than sand with narrow distribution. The broadening of the size distribution may be done either to the fine or the coarse side of the distribution or in both directions simultaneously, and a sand of higher density will result. Broadening to the coarse side has a greater effect on density than broadening the distribution to the fine sand. Wide size distributions favor green strength, while narrow grain distributions reduce it. The grain size distribution has a significant effect on permeability. Silica sand containing finer and a wide range of particle sizes will have low permeability as compared to those containing grains of average fineness but of the same size i.e. narrow distribution. The compactability is expressed by the green density obtained by three ram strokes. Finer the sand, the lower is the compactability and vice versa. This results from the fact that the specific surface increases as the grain size decreases. As a result, the number of points of contact per unit of volume increases and this in turn raises the resistance to compacting. The green strength has a certain tendency, admittedly not very pronounced, towards a maximum with a grain size which corresponds approximately to the medium grain size. As the silica sand grains become finer, the film of bentonite becomes thinner, although the percentage of bentonite remains the same. Due to reducing the thickness of binder film, the green strength is reduced. With very coarse grains, however, the number of grains and, therefore, the number of points of contact per unit of volume decreases so sharply that the green strength is again reduced. The sands with grains equal but coarser in size have greater void space and have, therefore greater permeability than the finer silica sands. This is more pronounced if sand grains are equal in size.

12.3.2 Binder

In general, the binders can be either inorganic or organic substance. The inorganic group includes clay sodium silicate and port land cement etc. In foundry shop, the clay acts as binder which may be Kaolonite, Ball Clay, Fire Clay, Limonite, Fuller's earth and Bentonite. Binders included in the organic group are dextrin, molasses, cereal binders, linseed oil and resins like phenol formaldehyde, urea formaldehyde etc. Organic binders are mostly used for core making. Among all the above binders, the bentonite variety of clay is the most common. However, this clay alone can not develop bonds among sand grins without the presence of moisture in molding sand and core sand.

12.3.3 Moisture

The amount of moisture content in the molding sand varies generally between 2 to 8 percent. This amount is added to the mixture of clay and silica sand for developing bonds. This is the amount of water required to fill the pores between the particles of clay without separating them. This amount of water is held rigidly by the clay and is mainly responsible for developing the strength in the sand. The effect of clay and water decreases permeability with increasing clay and moisture content. The green compressive strength first increases with the increase in clay content, but after a certain value, it starts decreasing.

For increasing the molding sand characteristics some other additional materials besides basic constituents are added which are known as additives.

12.3.4 Additives

Additives are the materials generally added to the molding and core sand mixture to develop

some special property in the sand. Some common used additives for enhancing the properties of molding and core sands are discussed as under.

12.3.4.1 Coal dust

Coal dust is added mainly for producing a reducing atmosphere during casting. This reducing atmosphere results in any oxygen in the poles becoming chemically bound so that it cannot oxidize the metal. It is usually added in the molding sands for making molds for production of grey iron and malleable cast iron castings.

12.3.4.2 Corn flour

It belongs to the starch family of carbohydrates and is used to increase the collapsibility of the molding and core sand. It is completely volatilized by heat in the mould, thereby leaving space between the sand grains. This allows free movement of sand grains, which finally gives rise to mould wall movement and decreases the mold expansion and hence defects in castings. Corn sand if added to molding sand and core sand improves significantly strength of the mold and core.

12.3.4.3 Dextrin

Dextrin belongs to starch family of carbohydrates that behaves also in a manner similar to that of the corn flour. It increases dry strength of the molds.

12.3.4.4 Sea coal

Sea coal is the fine powdered bituminous coal which positions its place among the pores of the silica sand grains in molding sand and core sand. When heated, it changes to coke which fills the pores and is unaffected by water: Because to this, the sand grains become restricted and cannot move into a dense packing pattern. Thus, sea coal reduces the mould wall movement and the permeability in mold and core sand and hence makes the mold and core surface clean and smooth.

12.3.4.5 Pitch

It is distilled form of soft coal. It can be added from 0.02 % to 2% in mold and core sand. It enhances hot strengths, surface finish on mold surfaces and behaves exactly in a manner similar to that of sea coal.

12.3.4.6 Wood flour

This is a fibrous material mixed with a granular material like sand; its relatively long thin fibers prevent the sand grains from making contact with one another. It can be added from 0.05 % to 2% in mold and core sand. It volatilizes when heated, thus allowing the sand grains room to expand. It will increase mould wall movement and decrease expansion defects. It also increases collapsibility of both of mold and core.

12.3.4.7 Silica flour

It is called as pulverized silica and it can be easily added up to 3% which increases the hot strength and finish on the surfaces of the molds and cores. It also reduces metal penetration in the walls of the molds and cores.

12.4 KINDS OF MOULDING SAND

Molding sands can also be classified according to their use into number of varieties which are described below.

12.4.1 Green sand

Green sand is also known as tempered or natural sand which is a just prepared mixture of silica sand with 18 to 30 percent clay, having moisture content from 6 to 8%. The clay and water furnish the bond for green sand. It is fine, soft, light, and porous. Green sand is damp, when squeezed in the hand and it retains the shape and the impression to give to it under pressure. Molds prepared by this sand are not requiring backing and hence are known as green sand molds. This sand is easily available and it possesses low cost. It is commonly employed for production of ferrous and non-ferrous castings.

12.4.2 Dry sand

Green sand that has been dried or baked in suitable oven after the making mold and cores, is called dry sand. It possesses more strength, rigidity and thermal stability. It is mainly suitable for larger castings. Mold prepared in this sand are known as dry sand molds.

12.4.3 Loam sand

Loam is mixture of sand and clay with water to a thin plastic paste. Loam sand possesses high clay as much as 30-50% and 18% water. Patterns are not used for loam molding and shape is given to mold by sweeps. This is particularly employed for loam molding used for large grey iron castings.

12.4.4 Facing sand

Facing sand is just prepared and forms the face of the mould. It is directly next to the surface of the pattern and it comes into contact molten metal when the mould is poured. Initial coating around the pattern and hence for mold surface is given by this sand. This sand is subjected severest conditions and must possess, therefore, high strength refractoriness. It is made of silica sand and clay, without the use of used sand. Different forms of carbon are used to prevent the metal burning into the sand. A facing sand mixture for green sand of cast iron may consist of 25% fresh and specially prepared and 5% sea coal. They are sometimes mixed with 6-15 times as much fine molding sand to make facings. The layer of facing sand in a mold usually ranges from 22-28 mm. From 10 to 15% of the whole amount of molding sand is the facing sand.

12.4.5 Backing sand

Backing sand or floor sand is used to back up the facing sand and is used to fill the whole volume of the molding flask. Used molding sand is mainly employed for this purpose. The backing sand is sometimes called black sand because that old, repeatedly used molding sand is black in color due to addition of coal dust and burning on coming in contact with the molten metal.

12.4.6 System sand

In mechanized foundries where machine molding is employed. A so-called system sand is used to fill the whole molding flask. In mechanical sand preparation and handling units, no facing sand is used. The used sand is cleaned and re-activated by the addition of water and special additives. This is known as system sand. Since the whole mold is made of this system sand, the properties such as strength, permeability and refractoriness of the molding sand must be higher than those of backing sand.

12.4.7 Parting sand

Parting sand without binder and moisture is used to keep the green sand not to stick to the pattern and also to allow the sand on the parting surface the cope and drag to separate without clinging. This is clean clay-free silica sand which serves the same purpose as parting dust.

12.4.8 Core sand

Core sand is used for making cores and it is sometimes also known as oil sand. This is highly rich silica sand mixed with oil binders such as core oil which composed of linseed oil, resin, light mineral oil and other bind materials. Pitch or flours and water may also be used in large cores for the sake of economy.

12.5 PROPERTIES OF MOULDING SAND

The basic properties required in molding sand and core sand are described as under.

12.5.1 Refractoriness

Refractoriness is defined as the ability of molding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting. It is a highly important characteristic of molding sands. Refractoriness can only be increased to a limited extent. Molding sand with poor refractoriness may burn on to the casting surface and no smooth casting surface can be obtained. The degree of refractoriness depends on the SiO_2 i.e. quartz content, and the shape and grain size of the particle. The higher the SiO_2 content and the rougher the grain volumetric composition the higher is the refractoriness of the molding sand and core sand. Refractoriness is measured by the sinter point of the sand rather than its-melting point.

12.5.2 Permeability

It is also termed as porosity of the molding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it. All these gaseous generated during pouring and solidification process must escape otherwise the casting becomes defective. Permeability is a function of grain size, grain shape, and moisture and clay contents in the molding sand. The extent of ramming of the sand directly affects the permeability of the mould. Permeability of mold can be further increased by venting using vent rods

12.5.3 Cohesiveness

It is property of molding sand by virtue which the sand grain particles interact and attract each other within the molding sand. Thus, the binding capability of the molding sand gets enhanced to increase the green, dry and hot strength property of molding and core sand.

12.5.4 Green strength

The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mould. For this, the sand grains must be adhesive, i.e. thev must be capable of attaching themselves to another body and. therefore, and sand grains having high adhesiveness will cling to the sides of the molding box. Also, the sand grains must have the property known as cohesiveness i.e. ability of the sand grains to stick

to one another. By virtue of this property, the pattern can be taken out from the mould without breaking the mould and also the erosion of mould wall surfaces does not occur during the flow of molten metal. The green strength also depends upon the grain shape and size, amount and type of clay and the moisture content.

12.5.5 Dry strength

As soon as the molten metal is poured into the mould, the moisture in the sand layer adjacent to the hot metal gets evaporated and this dry sand layer must have sufficient strength to its shape in order to avoid erosion of mould wall during the flow of molten metal. The dry strength also prevents the enlargement of mould cavity cause by the metallostatic pressure of the liquid metal.

12.5.6 Flowability or plasticity

It is the ability of the sand to get compacted and behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions. Generally sand particles resist moving around corners or projections. In general, flowability increases with decrease in green strength, an, decrease in grain size. The flowability also varies with moisture and clay content.

12.5.7 Adhesiveness

It is property of molding sand to get stick or adhere with foreign material such sticking of molding sand with inner wall of molding box

12.5.8 Collapsibility

After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal. In absence of this property the contraction of the metal is hindered by the mold and thus results in tears and cracks in the casting. This property is highly desired in cores

12.5.9 Miscellaneous properties

In addition to above requirements, the molding sand should not stick to the casting and should not chemically react with the metal. Molding sand should be cheap and easily available. It should be reusable for economic reasons. Its coefficients of expansion should be sufficiently low.

12.6 SAND TESTING

Molding sand and core sand depend upon shape, size composition and distribution of sand grains, amount of clay, moisture and additives. The increase in demand for good surface finish and higher accuracy in castings necessitates certainty in the quality of mold and core sands. Sand testing often allows the use of less expensive local sands. It also ensures reliable sand mixing and enables a utilization of the inherent properties of molding sand. Sand testing on delivery will immediately detect any variation from the standard quality, and adjustment of the sand mixture to specific requirements so that the casting defects can be minimized. It allows the choice of sand mixtures to give a desired surface finish. Thus sand testing is one of the dominating factors in foundry and pays for itself by obtaining lower per unit cost and

increased production resulting from sound castings. Generally the following tests are performed to judge the molding and casting characteristics of foundry sands:

1. Moisture content Test
2. Clay content Test
3. Chemical composition of sand
4. Grain shape and surface texture of sand.
5. Grain size distribution of sand
6. Specific surface of sand grains
7. Water absorption capacity of sand
8. Refractoriness of sand
9. Strength Test
10. Permeability Test
11. Flowability Test
12. Shatter index Test
13. Mould hardness Test.

Some of the important sand tests are discussed as under.

12.6.1 Moisture Content Test

The moisture content of the molding sand mixture may determined by drying a weighed amount of 20 to 50 grams of molding sand to a constant temperature up to 100°C in a oven for about one hour. It is then cooled to a room temperature and then reweighing the molding sand. The moisture content in molding sand is thus evaporated. The loss in weight of molding sand due to loss of moisture, gives the amount of moisture which can be expressed as a percentage of the original sand sample. The percentage of moisture content in the molding sand can also be determined in fact more speedily by an instrument known as a speedy moisture teller. This instrument is based on the principle that when water and calcium carbide react, they form acetylene gas which can be measured and this will be directly proportional to the moisture content. This instrument is provided with a pressure gauge calibrated to read directly the percentage of moisture present in the molding sand. Some moisture testing instruments are based on principle that the electrical conductivity of sand varies with moisture content in it.

12.6.2 Clay Content Test

The amount of clay is determined by carrying out the clay content test in which clay in molding sand of 50 grams is defined as particles which when suspended in water, fail to settle at the rate of one inch per min. Clay consists of particles less than 20 micron, per 0.0008 inch in dia.

12.6.3 Grain Fineness Test

For carry out grain fineness test a sample of dry silica sand weighing 50 gms free from clay is placed on a top most sieve bearing U.S. series equivalent number 6. A set of eleven sieves having U.S. Bureau of standard meshes 6, 12, 20, 30, 40, 50, 70, 100, 140, 200 and 270 are mounted on a mechanical shaker (Fig. 12.1). The series are placed in order of fineness from

top to bottom. The free silica sand sample is shaked in a mechanical shaker for about 15 minutes. After this weight of sand retained in each sieve is obtained sand and the retained sand in each sieve is multiplied by 2 which gives % of weight retained by each sieve. The same is further multiplied by a multiplying factor and total product is obtained. It is then divided by total % sand retained by different sieves which will give G.F.N.

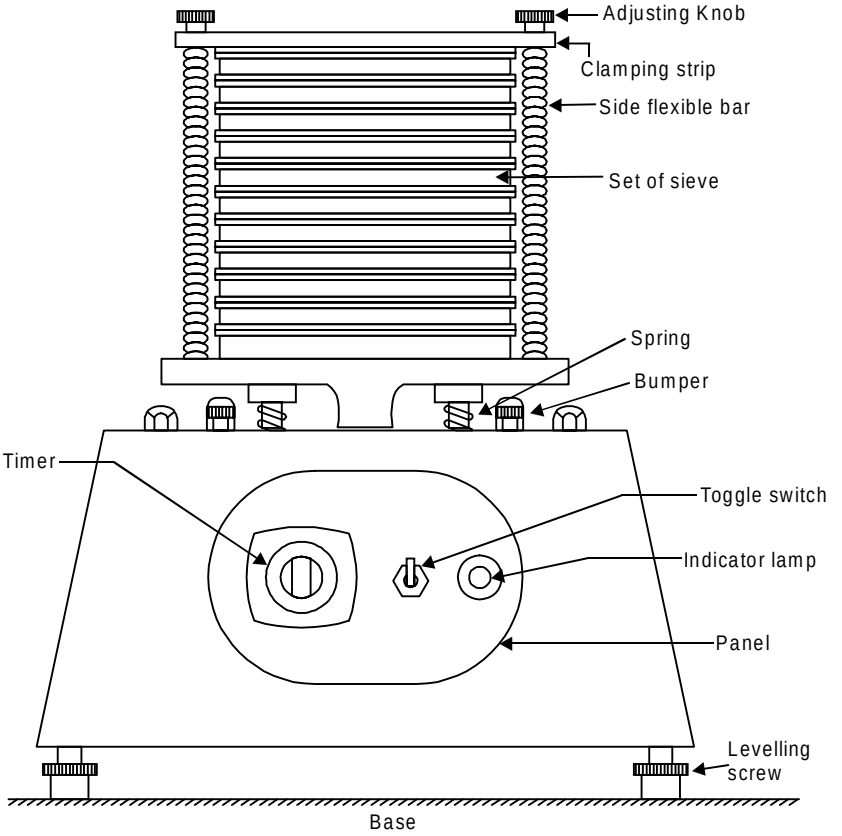


Fig. 12.1 Grain fitness testing mecanical shaker

12.6.4 Refractoriness Test

The refractoriness of the molding sand is judged by heating the American Foundry Society (A.F.S) standard sand specimen to very high temperatures ranges depending upon the type of sand. The heated sand test pieces are cooled to room temperature and examined under a microscope for surface characteristics or by scratching it with a steel needle. If the silica sand grains remain sharply defined and easily give way to the needle. Sintering has not yet set in. In the actual experiment the sand specimen in a porcelain boat is p1aced into an e1ectric furnace. It is usual practice to start the test from l000°C and raise the temperature in steps of 100°C to 1300°C and in steps of 50° above 1300°C till sintering of the silica sand grains takes place. At each temperature level, it is kept for at least three minutes and then taken out from the oven for examination under a microscope for evaluating surface characteristics or by scratching it with a steel needle.

12.6. 5 Strength Test

Green strength and dry strength is the holding power of the various bonding materials. Generally green compression strength test is performed on the specimen of green sand (wet condition). The sample specimen may of green sand or dry sand which is placed in lugs and compressive force is applied slowly by hand wheel until the specimen breaks. The reading of the needle of high pressure and low pressure manometer indicates the compressive strength of the specimen in kgf/cm^2. The most commonly test performed is compression test which is carried out in a compression sand testing machine (Fig. 12.2). Tensile, shear and transverse tests are also sometimes performed. Such tests are performed in strength tester using hydraulic press. The monometers are graduated in different scales. Generally sand mixtures are tested for their compressive strength, shear strength, tensile strength and bending strength. For carrying out these tests on green sand sufficient rammed samples are prepared to use. Although the shape of the test specimen differs a lot according to the nature of the test for all types of the strength tests can be prepared with the of a typical rammer and its accessories. To prepare cylindrical specimen bearing 50.8 mm diameter with for testing green sand, a defined amount of sand is weighed which will be compressed to height of 50.8 mm. by three repeated rammings. The predetermined amount of weighed molding sand is poured into the ram tube mounted on the bottom. Weight is lifted by means of the hand 1ever and the tube filled with sand is placed on the apparatus and the ramming unit is allowed to come down slowly to its original position. Three blows are given on the sample by allowing the rammer weight to fall by turning the lever. After the three blows the mark on the ram rod should lie between the markings on the stand. The rammed specimen is removed from the tube by means a pusher rod. The process of preparing sand specimen for testing dry sand is similar to the process as prepared before, with the difference that a split ram tube is used. The specimen for testing bending strength is of a square cross section. The various tests can be performed on strength tester. The apparatus can be compared with horizontal hydraulic press. Oil pressure is created by the hand-wheel and the pressure developed can be measured by two pressure manometers. The hydraulic pressure pushes the plunger. The adjusting cock serves to connect the two manometers. Deformation can be measured on the dial.

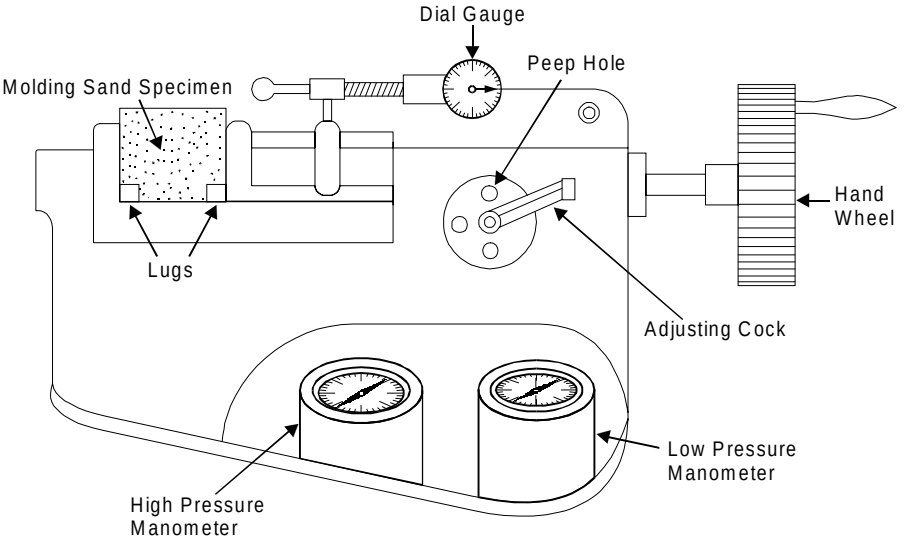


Fig. 12.2 Strength testing machine

The compression strength of the molding sand is determined by placing standard specimen at specified location and the load is applied on the standard sand specimen to compress it by uniform increasing load using rotating the hand wheel of compression strength testing set-up. As soon as the sand specimen fractures for break, the compression strength is measured by the manometer. Also, other strength tests can be conducted by adopting special types of specimen holding accessories.

12.6.6 Permeability Test

Initially a predetermined amount of molding sand is being kept in a standard cylindrical tube, and the molding sand is compressed using slightly tapered standard ram till the cylindrical standard sand specimen having 50.8mm diameter with 50.8 mm height is made and it is then extracted. This specimen is used for testing the permeability or porosity of molding and the core sand. This test is applied for testing porosity of the standard sand specimen. The test is performed in a permeability meter consisting of the balanced tank, water tank, nozzle, adjusting lever, nose piece for fixing sand specimen and a manometer. A typical permeability meter is shown in Fig. 12.3 which permits to read the permeability directly. The permeability test apparatus comprises of a cylinder and another concentric cylinder inside the outer cylinder and the space between the two concentric cylinders is filled with water. A bell having a diameter larger than that of the inner cylinder but smaller than that of outer cylinder, rests on the surface of water. Standard sand specimen of 5.08 mm diameter and 50.8 mm height together with ram tube is placed on the tapered nose piece of the permeability meter. The bell is allowed to sink under its own weight by the help of multi-position cock. In this way the air of the bell streams through the nozzle of nosepiece and the permeability is directly measured.

Permeability is volume of air (in cm^3) passing through a sand specimen of 1 cm^2 cross-sectional area and 1 cm height, at a pressure difference of 1 gm/cm^2 in one minute. In general, permeability is expressed as a number and can be calculated from the relation

$$P = vh/pat$$

Where, P = permeability

v = volume of air passing through the specimen in c.c.

h = height of specimen in cm

p = pressure of air in gm/cm^2

a = cross-sectional area of the specimen in cm^2

t = time in minutes.

For A.F S. standard permeability meter, 2000 cc of air is passed through a sand specimen (5.08 cm in height and 20.268 sq. cm. in cross-sectional area) at a pressure of 10 gms/cm^2 and the total time measured is 10 seconds = 1/6 min. Then the permeability is calculated using the relationship as given as under.

$$P = (2000 \times 5.08) / (10 \times 20.268 \times (1/6)) = 300.66 \text{ App.}$$

12.6.7 Flowability Test

Flowability of the molding and core sand usually determined by the movement of the rammer plunger between the fourth and fifth drops and is indicated in percentages. This reading can directly be taken on the dial of the flow indicator. Then the stem of this indicator rests again top of the plunger of the rammer and it records the actual movement of the plunger between the fourth and fifth drops.

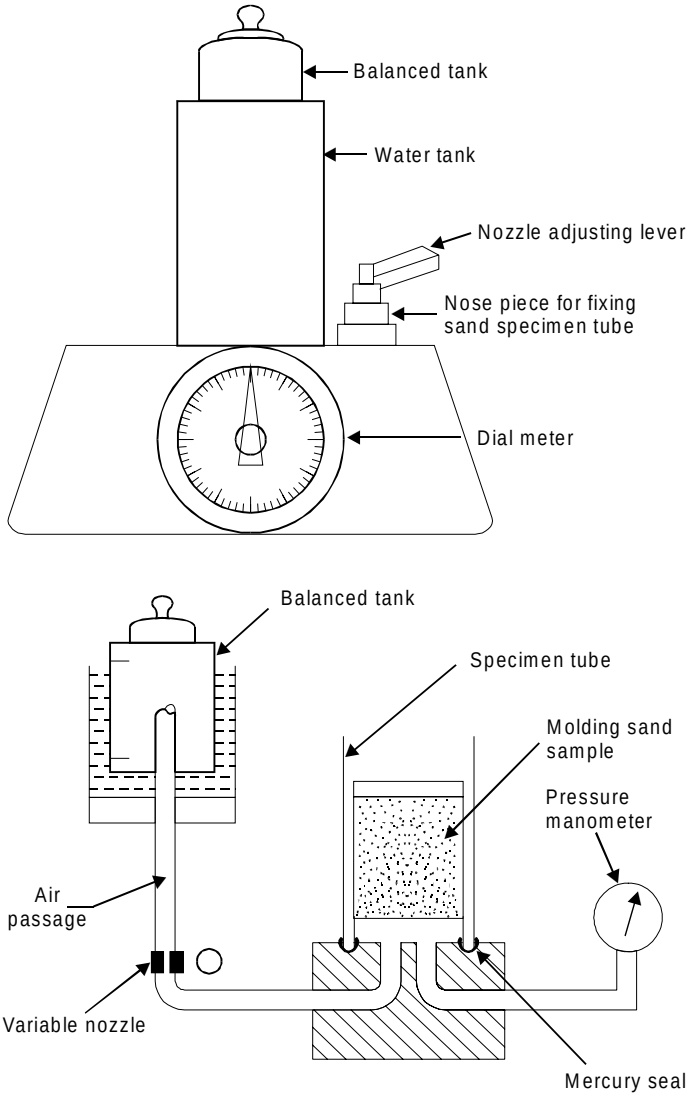


Fig. 12.3 Permeability meter

12.6.8 Shatter Index Test

In this test, the A.F.S. standard sand specimen is rammed usually by 10 blows and then it is allowed to fall on a half inch mesh sieve from a height of 6 ft. The weight of sand retained on the sieve is weighed. It is then expressed as percentage of the total weight of the specimen which is a measure of the shatter index.

12.6.9 Mould Hardness Test

This test is performed by a mold hardness tester shown in Fig. 12.4. The working of the tester is based on the principle of Brinell hardness testing machine. In an A.F.S. standard hardness tester a half inch diameter steel hemi-spherical ball is loaded with a spring load of 980 gm. This ball is made to penetrate into the mold sand or core sand surface. The penetration

of the ball point into the mould surface is indicated on a dial in thousands of an inch. The dial is calibrated to read the hardness directly i.e. a mould surface which offers no resistance to the steel ball would have zero hardness value and a mould which is more rigid and is capable of completely preventing the steel ball from penetrating would have a hardness value of 100. The dial gauge of the hardness tester may provide direct readings

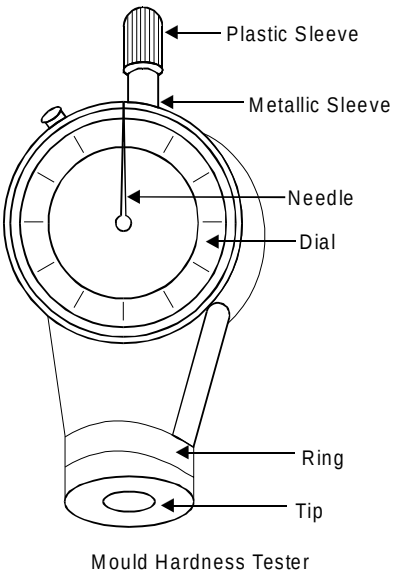


Fig. 12.4 Mould harness tester

12.7 SAND CONDITIONING

Natural sands are generally not well suited for casting purposes. On continuous use of molding sand, the clay coating on the sand particles gets thinned out causing decrease in its strength. Thus proper sand conditioning accomplish uniform distribution of binder around the sand grains, control moisture content, eliminate foreign particles and aerates the sands. Therefore, there is a need for sand conditioning for achieving better results.

The foreign materials, like nails, gaggers, hard sand lumps and metals from the used sand are removed. For removing the metal pieces, particularly ferrous pieces, the sand from the shake-out station is subjected to magnetic separator, which separates out the iron pieces, nails etc. from the used sand. Next, the sand is screened in riddles which separate out the hard sand lumps etc. These riddles may be manual as well as mechanical. Mechanical riddles may be either compressed air operated or electrically operated. But the electrically operated riddles are faster and can handle large quantities of sand in a short time. The amount of fine material can be controlled to the maximum possible extent by its removal through exhaust systems under conditions of shake out.

The sand constituents are then brought at required proper proportion and mixed thoroughly. Next, the whole mixture is mulled suitably till properties are developed. After all the foreign particles are removed from and the sand is free from the hard lumps etc., proper amount of pure sand, clay and required additives are added to for the loss because of the burned, clay and other corn materials. As the moisture content of the returned sand known, it is to be tested and after knowing the moisture the required amount of water is added. Now these things are mixed thoroughly in a mixing muller (Fig 12.5).

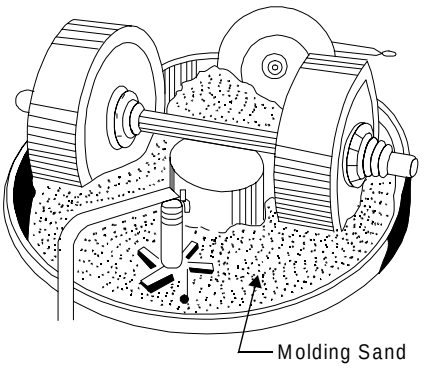


Fig. 12.5 Sand mixing muller

The main objectives of a mixing muller is to distribute the binders, additives and moisture or water content uniformly all around each sand grain and helps to develop the optimum physical properties by kneading on the sand grains. Inadequate mulling makes the sand

mixture weak which can only be compensated by adding more binder. Thus the adequate mulling economizes the use of binders. There are two methods of adding clay and water to sand. In the first method, first water is added to sand follow by clay, while in the other method, clay addition is followed water. It has been suggested that the best order of adding ingredients to clay bonded sand is sand with water followed by the binders. In this way, the clay is more quickly and uniformly spread on to all the sand grains. An additional advantage of this mixing order is that less dust is produced during the mulling operation. The muller usually consists of a cylindrical pan in which two heavy rollers; carrying two ploughs, and roll in a circular path. While the rollers roll, the ploughs scrap the sand from the sides and the bottom of the pan and place it in front of For producing a smearing action in the sand, the rollers are set slightly off the true radius and they move out of the rollers can be moved up and down without difficulty mounted on rocker arms. After the mulling is completed sand can be discharged through a door. The mechanical aerators are generally used for aerating or separating the sand grains by increasing the flowability through whirling the sand at a high speed by an impeller towards the inner walls of the casting. Aerating can also be done by riddling the sand mixture oil on a one fourth inch mesh screen or by spraying the sand over the sand heap by flipping the shovels. The aeration separates the sand grains and leaves each grain free to flow in the direction of ramming with less friction. The final step in sand conditioning is the cooling of sand mixture because of the fact that if the molding sand mixture is hot, it will cause molding difficulties.

12.8 STEPS INVOLVED IN MAKING A SAND MOLD

1. Initially a suitable size of molding box for creating suitable wall thickness is selected for a two piece pattern. Sufficient care should also be taken in such that sense that the molding box must adjust mold cavity, riser and the gating system (sprue, runner and gates etc.).
2. Next, place the drag portion of the pattern with the parting surface down on the bottom (ram-up) board as shown in Fig. 12.6 (a).
3. The facing sand is then sprinkled carefully all around the pattern so that the pattern does not stick with molding sand during withdrawn of the pattern.
4. The drag is then filled with loose prepared molding sand and ramming of the molding sand is done uniformly in the molding box around the pattern. Fill the molding sand once again and then perform ramming. Repeat the process three four times,
5. The excess amount of sand is then removed using strike off bar to bring molding sand at the same level of the molding flask height to completes the drag.
6. The drag is then rolled over and the parting sand is sprinkled over on the top of the drag [Fig. 12.6(b)].
7. Now the cope pattern is placed on the drag pattern and alignment is done using dowel pins.
8. Then cope (flask) is placed over the rammed drag and the parting sand is sprinkled all around the cope pattern.

9. Sprue and riser pins are placed in vertically position at suitable locations using support of molding sand. It will help to form suitable sized cavities for pouring molten metal etc. [Fig. 12.6 (c)].
10. The gaggers in the cope are set at suitable locations if necessary. They should not be located too close to the pattern or mold cavity otherwise they may chill the casting and fill the cope with molding sand and ram uniformly.
11. Strike off the excess sand from the top of the cope.
12. Remove sprue and riser pins and create vent holes in the cope with a vent wire. The basic purpose of vent creating vent holes in cope is to permit the escape of gases generated during pouring and solidification of the casting.
13. Sprinkle parting sand over the top of the cope surface and roll over the cope on the bottom board.
14. Rap and remove both the cope and drag patterns and repair the mold suitably if needed and dressing is applied
15. The gate is then cut connecting the lower base of sprue basin with runner and then the mold cavity.
16. Apply mold coating with a swab and bake the mold in case of a dry sand mold.
17. Set the cores in the mold, if needed and close the mold by inverting cope over drag.
18. The cope is then clamped with drag and the mold is ready for pouring, [Fig. 12.6 (d)].

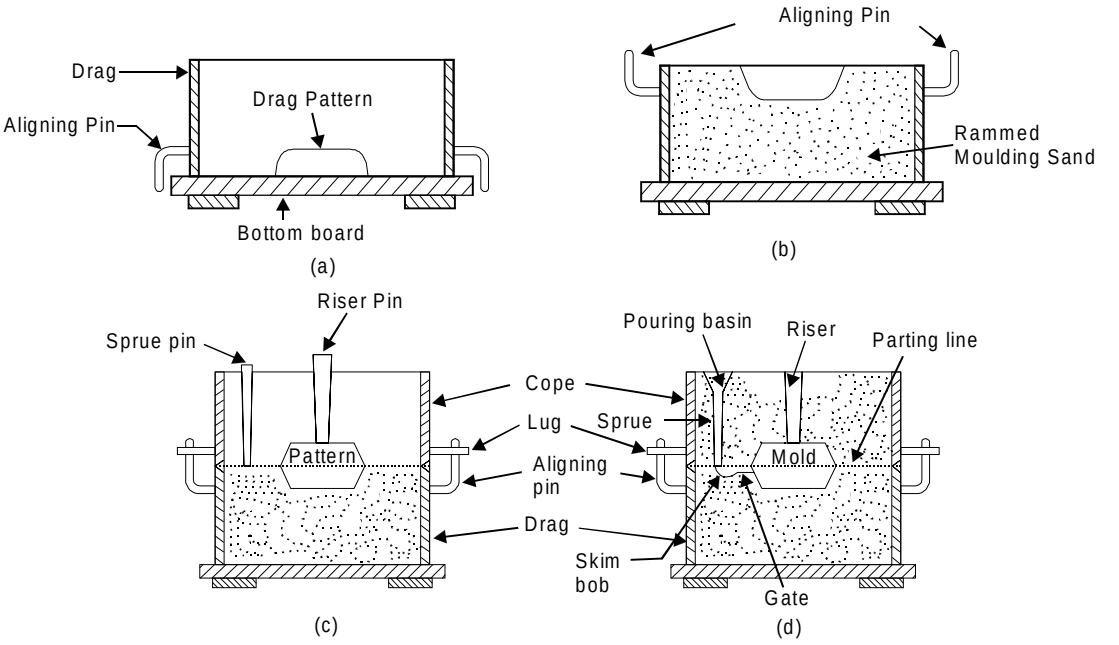


Fig. 12.6 Mold making

Example of making another mold is illustrated through Fig. 12.7

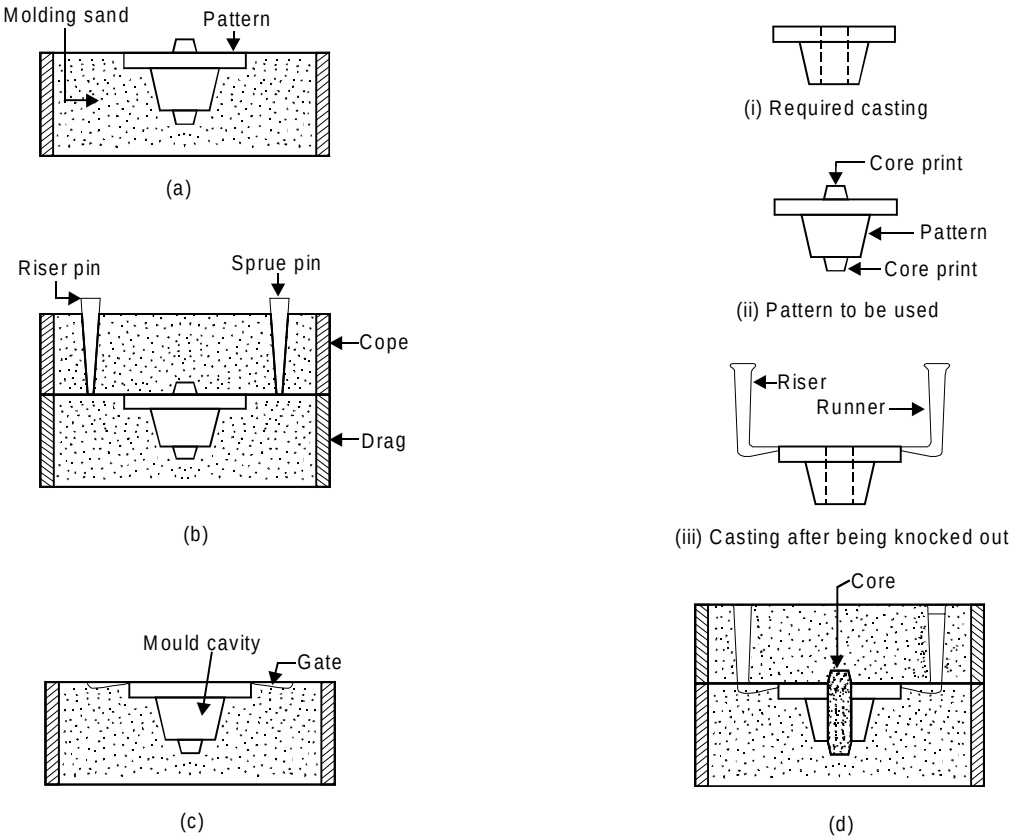


Fig. 12.7 Example of making a mold

12.9 VENTING OF MOLDS

Vents are very small pin types holes made in the cope portion of the mold using pointed edge of the vent wire all around the mold surface as shown in Fig. 12.8. These holes should reach just near the pattern and hence mold cavity on withdrawal of pattern. The basic purpose of vent holes is to permit the escape of gases generated in the mold cavity when the molten metal is poured. Mold gases generate because of evaporation of free water or steam formation, evolution of combined water (steam formation), decomposition of organic materials such as binders and additives (generation of hydrocarbons, CO and CO_2), expansion of air present in the pore spaces of rammed sand. If mold gases are not permitted to escape, they may get trapped in the metal and produce defective castings. They may raise back pressure and resist the inflow of molten metal. They may burst the mold. It is better to make many small vent holes rather than a few large ones to reduce the casting defects.

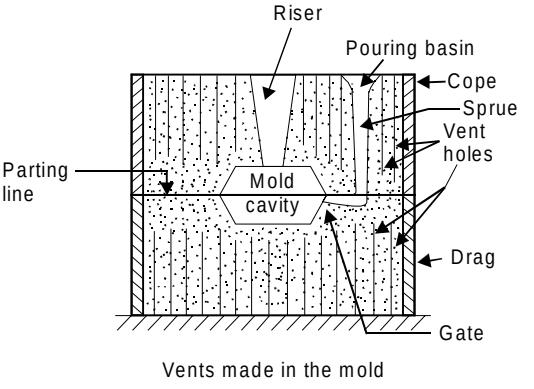


Fig. 12.8 Venting of holes in mold

12.10 GATING SYSTEM IN MOLD

Fig 12.9 shows the different elements of the gating system. Some of which are discussed as under.

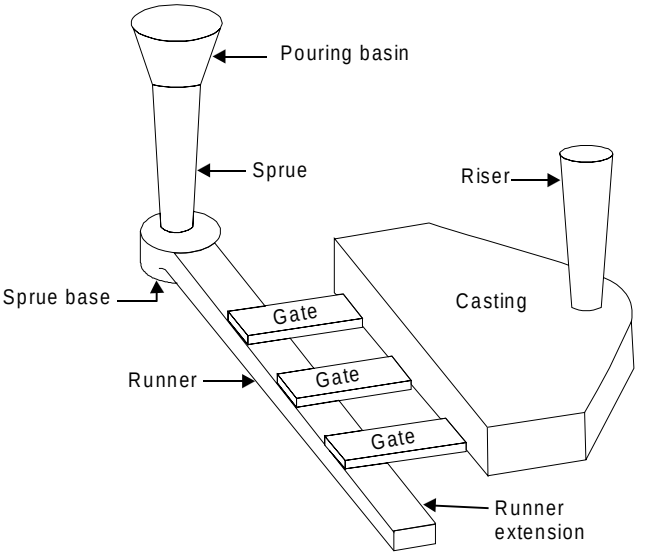


Fig. 12.9 Gating System

1. Pouring basin

It is the conical hollow element or tapered hollow vertical portion of the gating system which helps to feed the molten metal initially through the path of gating system to mold cavity. It may be made out of core sand or it may be cut in cope portion of the sand mold. It makes easier for the ladle operator to direct the flow of molten metal from crucible to pouring basin and sprue. It helps in maintaining the required rate of liquid metal flow. It reduces turbulence and vertexing at the sprue entrance. It also helps in separating dross, slag and foreign element etc. from molten metal before it enters the sprue.

2. Sprue

It is a vertical passage made generally in the cope using tapered sprue pin. It is connected at bottom of pouring basin. It is tapered with its bigger end at to receive the molten metal the smaller end is connected to the runner. It helps to feed molten metal without turbulence to the runner which in turn reaches the mold cavity through gate. It some times possesses skim bob at its lower end. The main purpose of skim bob is to collect impurities from molten metal and it does not allow them to reach the mold cavity through runner and gate.

3. Gate

It is a small passage or channel being cut by gate cutter which connect runner with the mould cavity and through which molten metal flows to fill the mould cavity. It feeds the liquid metal to the casting at the rate consistent with the rate of solidification.

4. Choke

It is that part of the gating system which possesses smallest cross-section area. In choked system, gate serves as a choke, but in free gating system sprue serves as a choke.

5. Runner

It is a channel which connects the sprue to the gate for avoiding turbulence and gas entrapment.

6. Riser

It is a passage in molding sand made in the cope portion of the mold. Molten metal rises in it after filling the mould cavity completely. The molten metal in the riser compensates the shrinkage during solidification of the casting thus avoiding the shrinkage defect in the casting. It also permits the escape of air and mould gases. It promotes directional solidification too and helps in bringing the soundness in the casting.

7. Chaplets

Chaplets are metal distance pieces inserted in a mould either to prevent shifting of mould or locate core surfaces. The distances pieces in form of chaplets are made of parent metal of which the casting is. These are placed in mould cavity suitably which positions core and to give extra support to core and mould surfaces. Its main objective is to impart good alignment of mould and core surfaces and to achieve directional solidification. When the molten metal is poured in the mould cavity, the chaplet melts and fuses itself along with molten metal during solidification and thus forms a part of the cast material. Various types of chaplets are shown in Fig. 12.10. The use of the chaplets is depicted in Fig. 12.11.

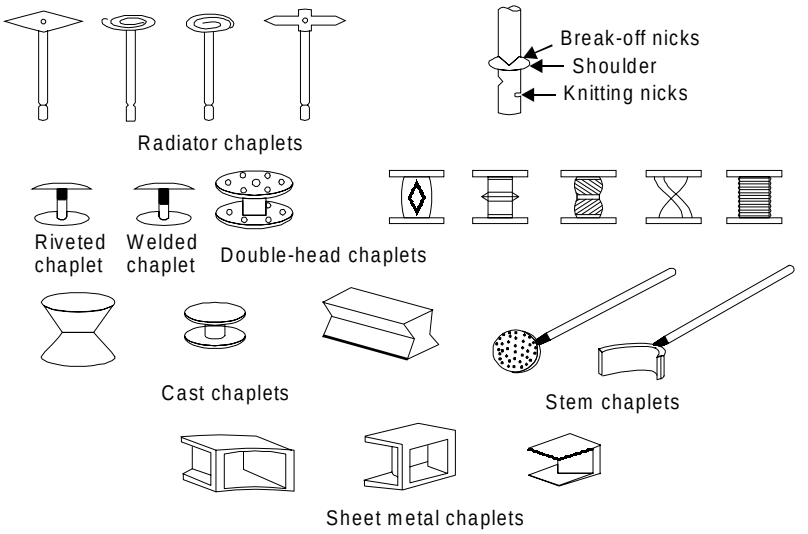


Fig. 12.10 Types of chaplets

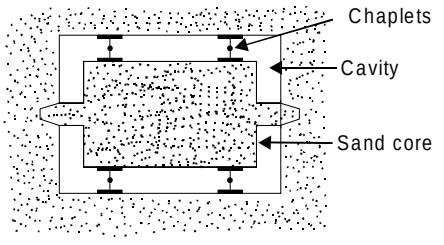


Fig. 12.11 Use of chaplets

8. Chills

In some casting, it is required to produce a hard surface at a particular place in the casting. At that particular position, the special mould surface for fast extraction of heat is to be made. The fast heat extracting metallic materials known as chills will be incorporated separately along with sand mould surface during molding. After pouring of molten metal and during solidification, the molten metal solidifies quickly on the metallic mould surface in comparison to other mold sand surfaces. This imparts hardness to that particular surface because of this special hardening treatment through fast extracting heat from that particular portion. Thus, the main function of chill is to provide a hard surface at a localized place in the casting by way of special and fast solidification. Various types of chills used in some casting processes are shown in Fig. 12.12. The use of a chill in the mold is depicted in Fig. 12.13.

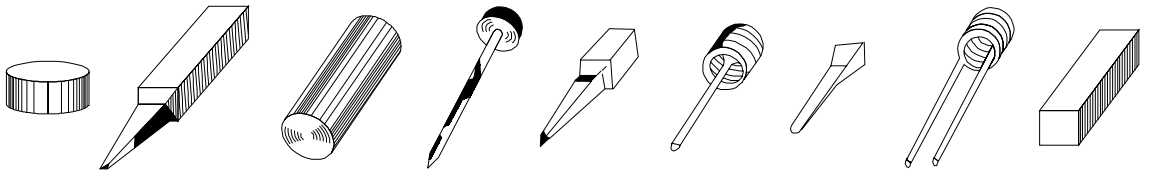


Fig. 12.12 Types of chills

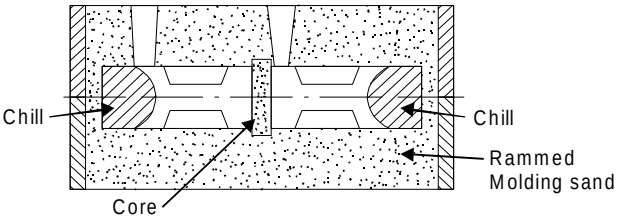


Fig. 12.13 Use of a chill

12.11 FACTORS CONTROLING GATING DESIGN

The following factors must be considered while designing gating system.

(*i*) Sharp corners and abrupt changes in at any section or portion in gating system should be avoided for suppressing turbulence and gas entrapment. Suitable relationship must exist between different cross-sectional areas of gating systems.

(*ii*) The most important characteristics of gating system besides sprue are the shape, location and dimensions of runners and type of flow. It is also important to determine the position at which the molten metal enters the mould cavity.

(*iii*) Gating ratio should reveal that the total cross-section of sprue, runner and gate decreases towards the mold cavity which provides a choke effect.

(*iv*) Bending of runner if any should be kept away from mold cavity.

(*v*) Developing the various cross sections of gating system to nullify the effect of turbulence or momentum of molten metal.

(*vi*) Streamlining or removing sharp corners at any junctions by providing generous radius, tapering the sprue, providing radius at sprue entrance and exit and providing a basin instead pouring cup etc.

12.12 ROLE OF RISER IN SAND CASTING

Metals and their alloys shrink as they cool or solidify and hence may create a partial vacuum within the casting which leads to casting defect known as shrinkage or void. The primary function of riser as attached with the mould is to feed molten metal to accommodate shrinkage occurring during solidification of the casting. As shrinkage is very common casting defect in casting and hence it should be avoided by allowing molten metal to rise in riser after filling the mould cavity completely and supplying the molten metal to further feed the void occurred during solidification of the casting because of shrinkage. Riser also permits the escape of evolved air and mold gases as the mold cavity is being filled with the molten metal. It also indicates to the foundry man whether mold cavity has been filled completely or not. The suitable design of riser also helps to promote the directional solidification and hence helps in production of desired sound casting.

12.12.1 Considerations for Desiging Riser

While designing risers the following considerations must always be taken into account.

(A) Freezing time

1 For producing sound casting, the molten metal must be fed to the mold till it solidifies completely. This can be achieved when molten metal in riser should freeze at slower rate than the casting.

2 Freezing time of molten metal should be more for risers than casting. The quantative risering analysis developed by Caine and others can be followed while designing risers.

(B) Feeding range

1. When large castings are produced in complicated size, then more than one riser are employed to feed molten metal depending upon the effective freezing range of each riser.
2. Casting should be divided into divided into different zones so that each zone can be feed by a separate riser.
3. Risers should be attached to that heavy section which generally solidifies last in the casting.
4. Riser should maintain proper temperature gradients for continuous feeding throughout freezing or solidifying.

(C) Feed Volume Capacity

1 Riser should have sufficient volume to feed the mold cavity till the solidification of the entire casting so as to compensate the volume shrinkage or contraction of the solidifying metal.

2 The metal is always kept in molten state at all the times in risers during freezing of casting. This can be achieved by using exothermic compounds and electric arc feeding arrangement. Thus it results for small riser size and high casting yield.

3 It is very important to note that volume feed capacity riser should be based upon freezing time and freezing demand.

Riser system is designed using full considerations on the shape, size and the position or location of the riser in the mold.

12.12.2 Effect of Riser

Riser size affects on heat loss from top at open risers. Top risers are expressed as a percentage of total heat lost from the rises during solidification. Risers are generally kept cylindrical. Larger the riser, greater is the percentage of heat that flows out of top. Shape of riser may be cylindrical or cubical or of cuboids kind. If shape is cylindrical i.e. 4″ high and 4″ dia, insulated so that heat can pass only into the circumferential sand walls, with a constant K value of 13.7 min./sq.ft. Chvorinov's rule may be used to calculate the freezing time for cylinder as 13.7 min. The freezing time of a 4″ steel cube of same sand is 6.1 minutes and the freezing time of a 2″, 8″ and 8″ rectangular block is also 6.1 min. Since the solidification time as calculated of the cylinder is nearly twice as long as that of either the block of the cube. Hence cylindrical shape is always better. Insulation and shielding of molten metal in riser also plays a good role for getting sound casting

12.13 GREEN SAND MOLDING

Green sand molding is the most widely used molding process. The green sand used for molding consists of silica, water and other additives. One typical green sand mixture contains 10 to 15% clay binder, 4 to 6% water and remaining silica sand. The green sand mixture is prepared and used in the molding procedure described in section 12.8 is used to complete the mold (cope and drag). Cope and drag are then assembled and molten metal is poured while mould cavity is still green. It is neither dried nor baked. Green sand molding is preferred for making small and medium sized castings. It can also be applied for producing non-ferrous castings. It has some advantages which are given as under.

Advantages

1 It is adaptable to machine molding
2 No mould baking and drying is required.
3 Mold distortion is comparatively less than dry sand molding.

12.14 CORE

Cores are compact mass of core sand (special kind of molding sand) prepared separately that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting. The environment in which the core is placed is much different from that of the mold. In fact the core has to withstand the severe action of hot metal which completely surrounds it. They may be of the type of green sand core and dry sand core. Therefore the core must meet the following functions or objectives which are given as under.

1 Core produces hollowness in castings in form of internal cavities.
2 It must be sufficiently permeable to allow the easy escape of gases during pouring and solidification.
3 It may form a part of green sand mold
4 It may be deployed to improve mold surface.
5 It may provide external under cut features in casting.
6 It may be inserted to achieve deep recesses in the casting.
7 It may be used to strengthen the mold.
8 It may be used to form gating system of large size mold.

12.15 CORE SAND

It is special kind of molding sand. Keeping the above mentioned objectives in view, the special considerations should be given while selecting core sand. Those considerations involves (*i*) The cores are subjected to a very high temperature and hence the core sand should be highly refractory in nature (*ii*) The permeability of the core sand must be sufficiently high as compared to that of the molding sands so as to allow the core gases to escape through the limited area of the core recesses generated by core prints (*iii*) The core sand should not possess such materials which may produce gases while they come in contact with molten metal and (*iv*) The core sand should be collapsible in nature, i.e. it should disintegrate after the metal solidifies, because this property will ease the cleaning of the casting.

The main constituents of the core sand are pure silica sand and a binder. Silica sand is preferred because of its high refractoriness. For higher values of permeability sands with coarse grain size distribution are used. The main purpose of the core binder is to hold the grains together, impart strength and sufficient degree collapsibility. Beside these properties needed in the core sand, the binder should be such that it produces minimum amount of gases when the molt metal is poured in the mould. Although, in general the binder are inorganic as well as organic ones, but for core making, organic binders are generally preferred because they are combustible and can be destroyed by heat at higher temperatures thereby giving sufficient collapsibility to the core sand. The common binders which are used in making core sand as follows:

1. Cereal binder

It develops green strength, baked strength and collapsibility in core. The amount of these binders used varies from 0.2 to 2.2% by weight in the core sand.

2. Protein binder

It is generally used to increase collapsibility property of core.

3. Thermo setting resin

It is gaining popularity nowadays because it imparts high strength, collapsibility to core sand and it also evolve minimum amount of mold and core gases which may produce defects in the casting. The most common binders under this group are phenol formaldehyde and urea formaldehyde.

4. Sulphite binder

Sulphite binder is also sometimes used in core but along with certain amount of clay.

5. Dextrin

It is commonly added in core sand for increasing collapsibility and baked strength of core

6. Pitch

It is widely used to increase the hot strength of the core.

7. Molasses

It is generally used as a secondary binder to increase the hardness on baking. It is used in the form of molasses liquid and is sprayed on the cores before baking.

8. Core oil

It is in liquid state when it is mixed with the core sand but forms a coherent solid film holding the sand grains together when it is baked. Although, the core drying with certain core oils occurs at room temperature but this can be expedited by increasing the temperature. That is why the cores are made with core oils and are usually baked.

12.16 CORE MAKING

Core making basically is carried out in four stages namely core sand preparation, core making, core baking and core finishing. Each stage is explained as under.

12.16.1 Core Sand Preparation

Preparation of satisfactory and homogenous mixture of core sand is not possible by manual means. Therefore for getting better and uniform core sand properties using proper sand constituents and additives, the core sands are generally mixed with the help of any of the following mechanical means namely roller mills and core sand mixer using vertical revolving arm type and horizontal paddle type mechanisms. In the case of roller mills, the rolling action of the mulling machine along with the turning over action caused by the ploughs gives a uniform and homogeneous mixing. Roller mills are suitable for core sands containing cereal binders, whereas the core sand mixer is suitable for all types of core binders. These machines perform the mixing of core sand constituents most thoroughly.

12.16.2 Core Making Process Using Core Making Machines

The process of core making is basically mechanized using core blowing, core ramming and core drawing machines which are broadly discussed as under.

12.16.2.1 Core blowing machines

The basic principle of core blowing machine comprises of filling the core sand into the core box by using compressed air. The velocity of the compressed air is kept high to obtain a high velocity of core sand particles, thus ensuring their deposit in the remote corners the core box. On entering the core sand with high kinetic energy, the shaping and ramming of core is carried out simultaneously in the core box. The core blowing machines can be further classified into two groups namely small bench blowers and large floor blowers. Small bench blowers are quite economical for core making shops having low production. The bench blowers were first introduced during second war. Because of the high comparative productivity and simplicity of design, bench blowers became highly popular. The cartridge oriented sand magazine is considered to be a part of the core box equipment. However, one cartridge may be used for several boxes of approximately the same size. The cartridge is filled using hands. Then the core box and cartridge are placed in the machine for blowing and the right handle of the machine clamps the box and the left handle blows the core. In a swing type bench blower, the core sand magazine swings from the blowing to the filling position. There is also another type of bench blowing, which has a stationary sand magazine. It eliminates the time and effort of moving the magazine from filling to the blowing position. The floor model blowers have the advantage being more automation oriented. These floor model blowers possess stationary sand magazine and automatic control. One of the major drawbacks in core blowing is the channeling of sand in the magazine which may be prevented by agitating the sand in the sand magazine.

12.16.2.2 Core ramming machines

Cores can also be prepared by ramming core sands in the core boxes by machines based on the principles of squeezing, jolting and slinging. Out of these three machines, jolting and slinging are more common for core making.

12.16.2.3 Core drawing machines

The core drawing is preferred when the core boxes have deep draws. After ramming sand in it, the core box is placed on a core plate supported on the machine bed. A rapping action on the core box is produced by a vibrating vertical plate. This rapping action helps in drawing off the core from the core box. After rapping, the core box, the core is pulled up thus leaving the core on the core plate. The drawn core is then baked further before its use in mold cavity to produce hollowness in the casting.

12.16.3 Core baking

Once the cores are prepared, they will be baked in a baking ovens or furnaces. The main purpose of baking is to drive away the moisture and hard en the binder, thereby giving strength to the core. The core drying equipments are usually of two kinds namely core ovens and dielectric bakers. The core ovens are may be further of two type's namely continuous type oven and batch type oven. The core ovens and dielectric bakers are discussed as under.

12.16.3.1 Continuous type ovens

Continuous type ovens are preferred basically for mass production. In these types, core carrying conveyors or chain move continuously through the oven. The baking time is controlled by the speed of the conveyor. The continuous type ovens are generally used for baking of small cores.

12.16.3.2 Batch type ovens

Batch type ovens are mainly utilized for baking variety of cores in batches. The cores are commonly placed either in drawers or in racks which are finally placed in the ovens. The core ovens and dielectric bakers are usually fired with gas, oil or coal.

12.16.3.3 Dielectric bakers

These bakers are based on dielectric heating. The core supporting plates are not used in this baker because they interfere with the potential distribution in the electrostatic field. To avoid this interference, cement bonded asbestos plates may be used for supporting the cores. The main advantage of these ovens is that they are faster in operation and a good temperature control is possible with them.

After baking of cores, they are smoothened using dextrin and water soluble binders.

12.16.4 CORE FINISHING

The cores are finally finished after baking and before they are finally set in the mould. The fins, bumps or other sand projections are removed from the surface of the cores by rubbing or filing. The dimensional inspection of the cores is very necessary to achieve sound casting. Cores are also coated with refractory or protective materials using brushing dipping and spraying means to improve their refractoriness and surface finish. The coating on core prevents the molten metal from entering in to the core.

Bars, wires and arbors are generally used to reinforce core from inside as per size of core using core sand. For handling bulky cores, lifting rings are also provided.

12.17 GREEN SAND CORES

Green sand cores are made by green sand containing moist condition about 5% water and 15-30 % clay. It imparts very good permeability to core and thus avoids defects like shrinkage or voids in the casting. Green sand cores are not dried. They are poured in green condition and are generally preferred for simple, small and medium castings. The process of making green sand core consumes less time. Such cores possess less strength in comparison to dry sand cores and hence cannot be stored for longer period.

12.18 DRY SAND CORES

Dry sand cores are produced by drying the green sand cores to about 110°C. These cores possess high strength rigidity and also good thermal stability. These cores can be stored for long period and are more stable than green sand core. They are used for large castings. They also produce good surface finish in comparison to green sand cores. They can be handled more easily. They resist metal erosion. These types of cores require more floor space, more core material, high labor cost and extra operational equipment.

12.19 CLASSIFICATION OF MOLDING PROCESSES

Molding processes can be classified in a number of ways. Broadly they are classified either on the basis of the method used or on the basis of the mold material used.

(*i*) Classification based on the method used

(*a*) Bench molding. (*b*) Floor molding,

(*c*) Pit molding. (*d*) Machine molding.

(*ii*) Classification based on the mold material used:

(*a*) Sand molding:

1. Green sand mould
2. Dry sand mould,
3. Skin dried mould.
4. Core sand mould.
5. loam mould
6. Cement bonded sand mould
7. Carbon-dioxide mould.
8. Shell mould.

(*b*) Plaster molding,

(*c*) Metallic molding.

(*d*) Loam molding

Some of the important molding methods are discussed as under.

12.20 MOLDING METHODS

Commonly used traditional methods of molding are bench molding, floor molding, pit molding and machine molding. These methods are discussed as under.

12.20.1 Bench Molding

This type of molding is preferred for small jobs. The whole molding operation is carried out on a bench of convenient height. In this process, a minimum of two flasks, namely cope and drag molding flasks are necessary. But in certain cases, the number of flasks may increase depending upon the number of parting surfaces required.

12.20.2 Floor Molding

This type of molding is preferred for medium and large size jobs. In this method, only drag portion of molding flask is used to make the mold and the floor itself is utilized as drag and it is usually performed with dry sand.

12.20.3 Pit Molding

Usually large castings are made in pits instead of drag flasks because of their huge size. In pit molding, the sand under the pattern is rammed by bedding-in process. The walls and the bottom of the pit are usually reinforced with concrete and a layer of coke is laid on the bottom of the pit to enable easy escape of gas. The coke bed is connected to atmosphere through vent pipes which provide an outlet to the gases. One box is generally required to complete the mold, runner, sprue, pouring basin and gates are cut in it.

12.20.4 Machine Molding

For mass production of the casting, the general hand molding technique proves un economical and in efficient. The main advantage of machine molding, besides the saving of labor and working time, is the accuracy and uniformity of the castings which can otherwise be only obtained with much time and labor. Or even the cost of machining on the casting can be reduced drastically because it is possible to maintain the tolerances within narrow limits on casting using machine molding method. Molding machines thus prepare the moulds at a faster rate and also eliminate the need of employing skilled molders. The main operations performed by molding machines are ramming of the molding sand, roll over the mold, form gate, rapping the pattern and its withdrawal. Most of the mold making operations are performed using molding machines

12.19.5 Loam Molding

Loam molding uses loam sand to prepare a loam mold. It is such a molding process in which use of pattern is avoided and hence it differs from the other molding processes. Initially the loam sand is prepared with the mixture of molding sand and clay made in form of a paste by suitable addition of clay water. Firstly a rough structure of cast article is made by hand using bricks and loam sand and it is then given a desired shape by means of strickles and sweep patterns. Mould is thus prepared. It is then baked to give strength to resist the flow of molten metal. This method of molding is used where large castings are required in numbers. Thus it enables the reduction in time, labor and material which would have been spent in making a pattern. But this system is not popular for the reason that it takes lots of time in preparing mould and requires special skill. The cope and drag part of mould are constructed separately on two different iron boxes using different sizes of strickles and sweeps etc. and are assembled together after baking. It is important to note that loam moulds are dried slowly and completely and used for large regular shaped castings like chemical pans, drums etc.

12.19.6 Carbon-Dioxide Gas Molding

This process was widely used in Europe for rapid hardening the molds and cores made up of green sand. The mold making process is similar to conventional molding procedure accept the mould material which comprises of pure dry silica sand free from clay, 3-5% sodium silicate as binder and moisture content generally less than 3%. A small amount of starch may be added to improve the green compression strength and a very small quantity of coal dust, sea coal, dextrin, wood floor, pitch, graphite and sugar can also be added to improve the collapsibility of the molding sand. Kaolin clay is added to promote mold stability. The prepared molding sand is rammed around the pattern in the mould box and mould is prepared by any conventional technique. After packing, carbon dioxide gas at about 1.3-1.5 kg/cm^2 pressure is then forced all round the mold surface to about 20 to 30 seconds using CO_2 head or probe or curtain as shown in Fig. 12.14. The special pattern can also be used to force the carbon dioxide gas all round the mold surfaces. Cores can be baked this way. The sodium silicate presented in the mold reacts with CO_2 and produce a very hard constituents or substance commonly called as silica gel.

$$Na_2SiO_3 + CO_2 \longrightarrow Na_2CO_3 + SiO_2.xH_2O \text{ (Silica Gel)}$$

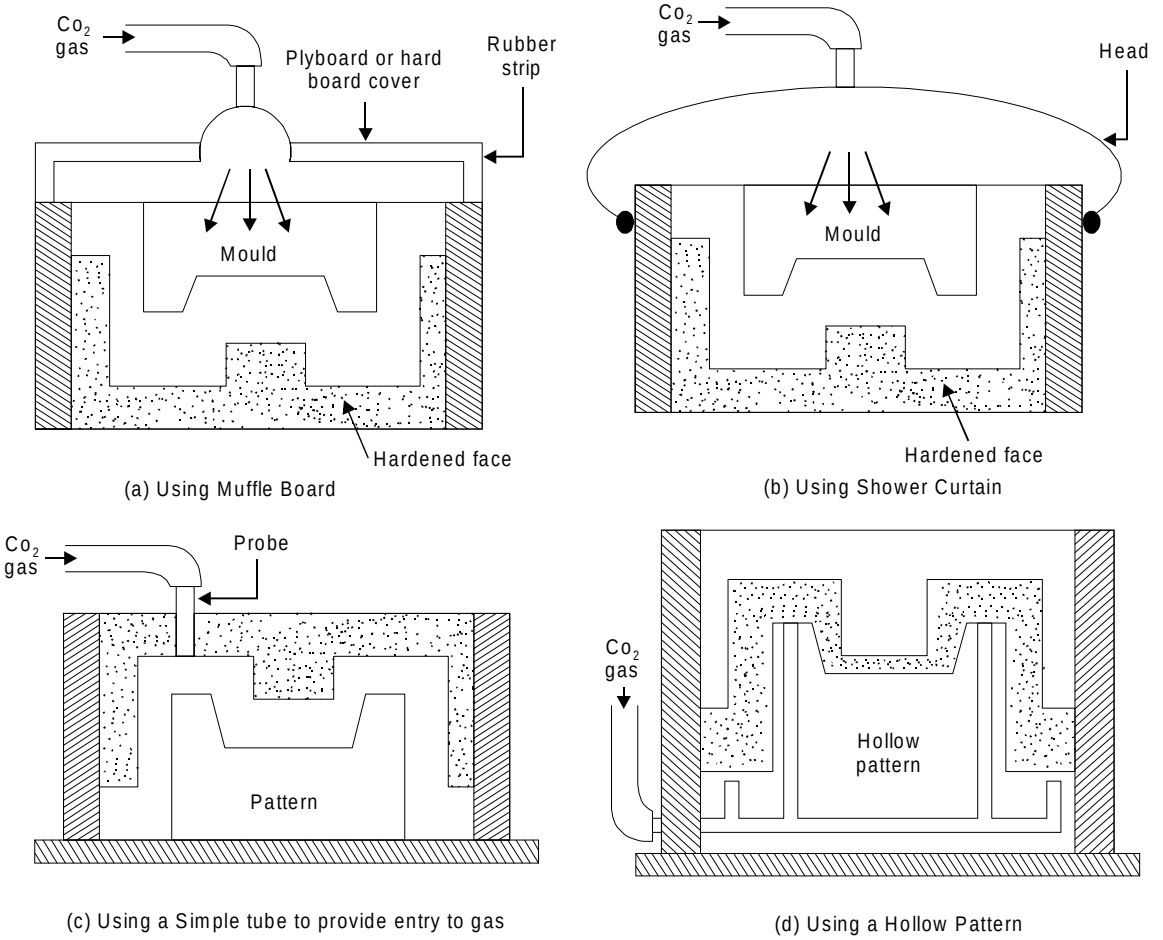


Fig. 12.14 Carbon dioxide molding

This hard substance is like cement and helps in binding the sand grains. Molds and cores thus prepared can be used for pouring molten metal for production of both ferrous and non-ferrous casting. The operation is quick, simple require semi-skilled worker. The evolution of gases is drastically reduced after pouring the thus prepared mould. This process eliminates mold and core baking oven. Reclamation of used sand is difficult for this process

Few other special molding methods are also discussed as under

12.20.6 Shell Molding

Shell mold casting is recent invention in molding techniques for mass production and smooth finish. Shell molding method was invented in Germany during the Second World War. It is also known as Carning or C process which is generally used for mass production of accurate thin castings with close tolerance of +_ 0.02 mm and with smooth surface finish. It consists of making a mould that has two or more thin lines shells (shell line parts, which are moderately hard and smooth. Molding sand is prepared using thermosetting plastic dry powder and find sand are uniformly mixed in a muller in the ratio 1: 20. In this process the pattern is placed on a metal plate and silicon grease is then sprayed on it. The pattern is then heated to 205°C to 230°C and covered with resin bonded sand. After 30 second a hard layer of sand is formed over the pattern. Pattern and shell are then heated and treated in an oven at 315°C for 60 sec. Then, the shell so formed as the shape of the pattern is ready to strip from the pattern. The shell can be made in two or more pieces as per the shape of pattern. Similarly core can be made by this process. Finally shells are joined together to form the mold cavity. Then the mold is ready for pouring the molten metal to get a casting. The shell so formed has the shape of pattern formed of cavity or projection in the shell. In case of unsymmetrical shapes, two patterns are prepared so that two shell are produced which are joined to form proper cavity. Internal cavity can be formed by placing a core. Hot pattern and box is containing a mixture of sand and resin. Pattern and box inverted and kept in this position for some time. Now box and pattern are brought to original position. A shell of resin-bonded sand sticks to the pattern and the rest falls. Shell separates from the pattern with the help of ejector pins. It is a suitable process for casting thin walled articles. The cast shapes are uniform and their dimensions are within close limit of tolerance ± 0.002 mm and it is suitable for precise duplication of exact parts.

The shells formed by this process are 0.3 to 0.6 mm thick and can be handled and stored. Shell moulds are made so that machining parts fit together-easily, held clamps or adhesive and metal is poured either in a vertical or horizontal position. They are supported in rocks or mass of bulky permeable material such as sand steel shot or gravel. Thermosetting plastics, dry powder and sand are mixed ultimately in a muller. The process of shell molding possesses various advantages and disadvantages. Some of the main advantages and disadvantages of this process are given as under.

Advantages

The main advantages of shell molding are:

(*i*) High suitable for thin sections like petrol engine cylinder.

(*ii*) Excellent surface finish.

(*iii*) Good dimensional accuracy of order of 0.002 to 0.003 mm.

(*iv*) Negligible machining and cleaning cost.

(*v*) Occupies less floor space.

(*vi*) Skill-ness required is less.
(*vii*) Moulds formed by this process can be stored until required.
(*viii*) Better quality of casting assured.
(*ix*) Mass production.
(*x*) It allows for greater detail and less draft.
(*xi*) Unskilled labor can be employed.
(*xii*) Future of shell molding process is very bright.

Disadvantages

The main disadvantages of shell molding are:

1. Higher pattern cost.
2. Higher resin cost.
3. Not economical for small runs.
4. Dust-extraction problem.
5. Complicated jobs and jobs of various sizes cannot be easily shell molded.
6. Specialized equipment is required.
7. Resin binder is an expensive material.
8. Limited for small size.

12.20.7 Plaster Molding

Plaster molding process is depicted through Fig. 12.15. The mould material in plaster molding is gypsum or plaster of paris. To this plaster of paris, additives like talc, fibers, asbestos, silica flour etc. are added in order to control the contraction characteristics of the mould as well as the settling time. The plaster of paris is used in the form of a slurry which is made to a consistency of 130 to 180. The consistency of the slurry is defined as the pounds of water per 100 pounds of plaster mixture. This plaster slurry is poured over a metallic pattern confined in a flask. The pattern is usually made of brass and it is generally in the form of half portion of job to be cast and is attached firmly on a match plate which forms the bottom of the molding flask. Wood pattern are not used because the water in the plaster raises the grains on them and makes them difficult to be withdrawn. Some parting or release agent is needed for easy withdrawal of the pattern from the mold. As the flask is filled with the slurry, it is vibrated so as to bubble out any air entrapped in the slurry and to ensure that the mould is completely filled up. The plaster material is allowed to set. Finally when the plaster is set properly the pattern is then withdrawn by separating the same, from the plaster by blowing compressed air through the holes in the patterns leading to the parting surface between the pattern and the plaster mold. The plaster mold thus produced is dried in an oven to a temperature range between 200-700 degree centigrade and cooled in the oven itself. In the above manner two halves of a mould are prepared and are joined together to form the proper cavity. The necessary sprue, runner etc. are cut before joining the two parts.

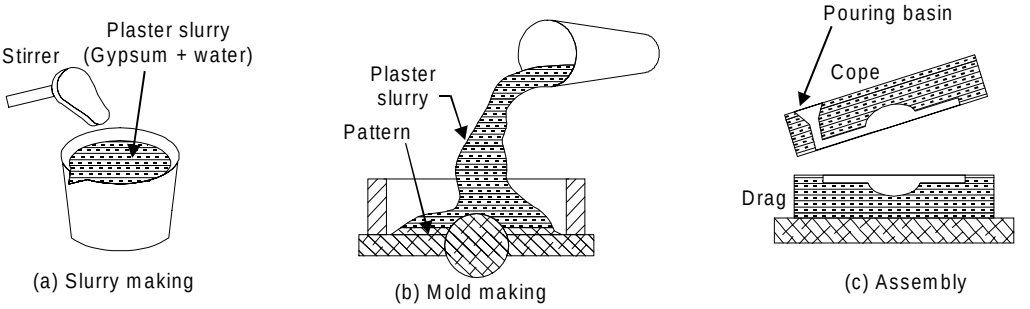


Fig. 12.15 Plaster molding

Advantages

(*a*) In plaster molding, very good surface finish is obtained and machining cost is also reduced.

(*b*) Slow and uniform rate of cooling of the casting is achieved because of low thermal conductivity of plaster and possibility of stress concentration is reduced.

(*c*) Metal shrinkage with accurate control is feasible and thereby warping and distortion of thin sections can be avoided in the plaster molding.

Limitations

(*a*) There is evolution of steam during metal pouring if the plaster mold is not dried at higher temperatures avoid this, the plaster mold may be dehydrated at high temperatures, but the strength of the mould decreases with dehydration.

(*b*) The permeability of the plaster mold is low. This may be to a certain extent but it can be increased by removing the bubbles as the plaster slurry is mixed in a mechanical mixer.

12.20.8 Antioch Process

This is a special case of plaster molding which was developed by Morris Bean. It is very well suited to high grade aluminum castings. The process differs from the normal plaster molding in the fact that in this case once the plaster sets the whole thing is auto-laved in saturated steam at about 20 psi. Then the mold is dried in air for about 10 to 12 hours and finally in an oven for 10 to 20 hours at about 250°C. The autoclaving and drying processes create a granular structure in the mold structure which increases its permeability.

12.20.9 Metallic Molding

Metallic mold is also known as permanent mold because of their long life. The metallic mold can be reused many times before it is discarded or rebuilt. Permanent molds are made of dense, fine grained, heat resistant cast iron, steel, bronze, anodized aluminum, graphite or other suitable refractoriness. The mold is made in two halves in order to facilitate the removal of casting from the mold. Usually the metallic mould is called as dies and the metal is introduced in it under gravity.

Some times this operation is also known as gravity die casting. When the molten metal is introduced in the die under pressure, then this process is called as pressure die casting. It may be designed with a vertical parting line or with a horizontal parting line as in

conventional sand molds. The mold walls of a permanent mold have thickness from 15 mm to 50 mm. The thicker mold walls can remove greater amount of heat from the casting. This provides the desirable chilling effect. For faster cooling, fins or projections may be provided on the outside of the permanent mold. Although the metallic mould can be used both for ferrous and nonferrous castings but this process is more popular for the non-ferrous castings, for examples aluminum alloys, zinc alloys and magnesium alloys. Usually the metallic molds are made of grey iron, alloy steels and anodized aluminum alloys. There are some advantages, dis-advantages and applications of metallic molding process which are discussed as under.

Advantages

(*i*) Fine and dense grained structure in casting is achieved using such mold.

(*ii*) No blow holes exist in castings produced by this method.

(*iii*) The process is economical.

(*iv*) Because of rapid rate of cooling, the castings possess fine grain structure.

(*v*) Close dimensional tolerance is possible.

(*vi*) Good surface finish and surface details are obtained.

(*vii*) Casting defects observed in sand castings are eliminated.

(*viii*) Fast rate of production can be attained.

(*ix*) The process requires less labor.

Disadvantages

(*i*) The surface of casting becomes hard due to chilling effect.

(*ii*) High refractoriness is needed for high melting point alloys.

(*iii*) The process is impractical for large castings.

Applications

1 This method is suitable for small and medium sized casting.

2 It is widely suitable for non-ferrous casting.

12.21 QUESTIONS

1. Explain briefly the main constituents of molding sand.
2. How do the grain size and shape affect the performance of molding sand?
3. How natural molding sands differ from synthetic sands? Name major sources of obtaining natural molding sands in India?
4. How are binders classified?
5. Describe the process of molding sand preparation and conditioning.
6. Name and describe the different properties of good molding sand.
7. What are the common tests performed on molding sands?
8. Name and describe briefly the different additives commonly added to the molding sand for improving the properties of the molding sand.
9. What are the major functions of additives in molding sands?
10. Classify and discuss the various types of molding sand. What are the main factors which influence the selection of particular molding sand for a specific use?

11. What is meant by green strength and dry strength as applied to a molding sand?
12. What is grain fineness number? Explain how you will use a sieve shaker for determining the grain fineness of foundry sand.
13. How will you test the moisture content and clay content in molding sand?
14. Using the neat sketches, describe procedural steps to be followed in making dry sand mold.
15. Differentiate between the process of green sand molding and dry sand molding.
16. Sketch a complete mold and indicate on it the various terms related to it and their functions.
17. Discuss briefly the various types of molds.
18. Explain the procedure of making a mold using a split pattern.
19. Write short notes of the following:
    (*i*) Floor molding
    (*ii*) Pit molding
    (*iii*) Bench molding
    (*iv*) Machine molding
    (*v*) Loam molding.
    (*vi*) Plaster molding.
    (*vii*) Metallic molding.
20. Describe the following:
    (*i*) Skin dried molds
    (*ii*) Air dried molds
    (*iii*) CO_2 molds
    (*iv*) Plaster molds.
21. What do you understand by the term gating system?
22. What are chaplets and why are they used?
23. Using neat sketches, describe various types of chaplets.
24. What do you understand by the term gating system?
25. What are the main requirements expected of an ideal gating system?
26. What are different types of gates? Explain them with the help of sketches stating the relative merits and demerits of each.
27. What is chill? Explain in brief its uses.
28. What is meant by the term 'risering'?
29. Discuss the common objectives of risers.
30. What advantages are provided by a riser?
31. What is the best shape of a riser, and why?
32. Why is cylindrical shape risers most commonly used?
33. What are the advantages of blind riser over conventional type riser?
34. Write short notes on the following terms:
    (*i*) Use of padding
    (*ii*) Use of exothermic materials and
    (*iii*) Use of chills to help proper directional solidification.

35. Describe the process of shell molding indicating:
    (*i*) Composition of sand mixture
    (*ii*) Steps in molding
    (*iii*) Advantages
    (*iv*) Limitations and
    (*v*) Applications.
36. Describe the CO_2–gas molding process in detail using suitable sketches and stat its advantages, disadvantages and applications.
37. What is a core? What purposes are served by cores?
38. What are the characteristics of a good core?
39. Classify the types of cores? Explain them with the help of sketches specifying their common applications.
40. What is a core binder?
41. What is core print?
42. Describe different types of core sand.
43. Describe hand core making and machine core making.
44. How are the cores finished and inspected?
45. What is the function of the core in sand molding? How are cores held in place in mold? And how are they supported?
46. Distinguish between green sand cores and dry sand cores?
47. Name the different steps in core-making? Describe the operation of making a dry sand core?
48. What are the different stages in core making?
49. What are the different types of machines used in core-making?
50. Describe the following terms used in core-making.
    (*i*) Core drying,
    (*ii*) Core finishing
    (*iii*) Use of rods, wires, arbors and lifting rings.

13 CHAPTER

CASTING

13.1 INTRODUNCTION

Casting process is one of the earliest metal shaping techniques known to human being. It means pouring molten metal into a refractory mold cavity and allows it to solidify. The solidified object is taken out from the mold either by breaking or taking the mold apart. The solidified object is called casting and the technique followed in method is known as casting process. The casting process was discovered probably around 3500 BC in Mesopotamia. In many parts of world during that period, copper axes (wood cutting tools) and other flat objects were made in open molds using baked clay. These molds were essentially made in single piece. The Bronze Age 2000 BC brought forward more refinement into casting process. For the first time, the core for making hollow sockets in the cast objects was invented. The core was made of baked sand. Also the lost wax process was extensively used for making ornaments using the casting process. Casting technology was greatly improved by Chinese from around 1500 BC. For this there is evidence of the casting activity found in China. For making highly intricate jobs, a lot of time in making the perfect mold to the last detail so hardly any finishing work was required on the casting made from the molds. Indus valley civilization was also known for their extensive use of casting of copper and bronze for ornaments, weapons, tools and utensils. But there was not much of improvement in the casting technology. From various objects that were excavated from the Indus valley sites, they appear to have been familiar with all the known casting methods such as open mold and piece mold. This chapter describes the fluidity of molten metal, different casting techniques and various casting defects occurring in casting processes.

13.2 SIGNIFICANCE OF FLUDITY

Fluidity of molten metal helps in producing sound casting with fewer defects. It fills not only the mold cavity completely and rapidly but does not allow also any casting defect like “misrun” to occur in the cast object. Pouring of molten metal properly at correct temperature plays a significant role in producing sound castings. The gating system performs the function to introduce clean metal into mold cavity in a manner as free of turbulence as possible. To produce sound casting gate must also be designed to completely fill the mold cavity for preventing casting defect such as misruns and to promote feeding for establishing proper temperature gradients. Prevent casting defect such as misruns without use of excessively high pouring temperatures is still largely a matter of experience. To fill the complicated

castings sections completely, flow rates must be high but not so high as to cause turbulence. It is noted that metal temperature may affect the ability of molten alloy to fill the mold, this effect is metal fluidity. 1t include alloy analysis and gas content, and heat-extracting power of the molding material. Often, it is desirable to check metal fluidity before pouring using fluidity test. Fig. 13.1 illustrates a standard fluidity spiral test widely used for cast steel. "Fluidity" of an alloy is rated as a distance, in inches, that the metal runs in the spiral channel. Fluidity tests, in which metal from the furnace is poured by controlled vacuum into a flow channel of suitable size, are very useful, since temperature (super-heat) is the most

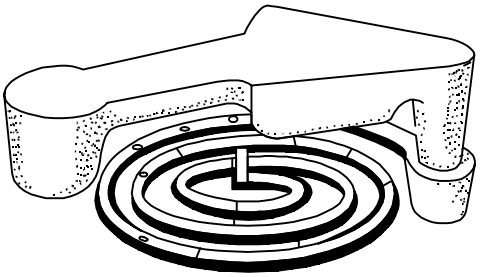


Fig. 13.1 Fluidity spiral test

significant single variable influencing the ability of molten metal to fill mold. This test is an accurate indicator of temperature. The use of simple, spiral test, made in green sand on a core poured by ladle from electric furnace steel melting where temperature measurement is costly and inconvenient. The fluidity test is same times less needed except as a research tool, for the lower melting point metals, where pyrometry is a problem. In small casting work, pouring is done by means of ladles and crucibles.

There are some special casting methods which are discussed as under.

13.3 PERMANENT MOLD OR GRAVITY DIE CASTING

This process is commonly known as permanent mold casting in U.S.A and gravity die casting in England. A permanent mold casting makes use of a mold or metallic die which is permanent. A typical permanent mold is shown in Fig. 13.2. Molten metal is poured into the mold under

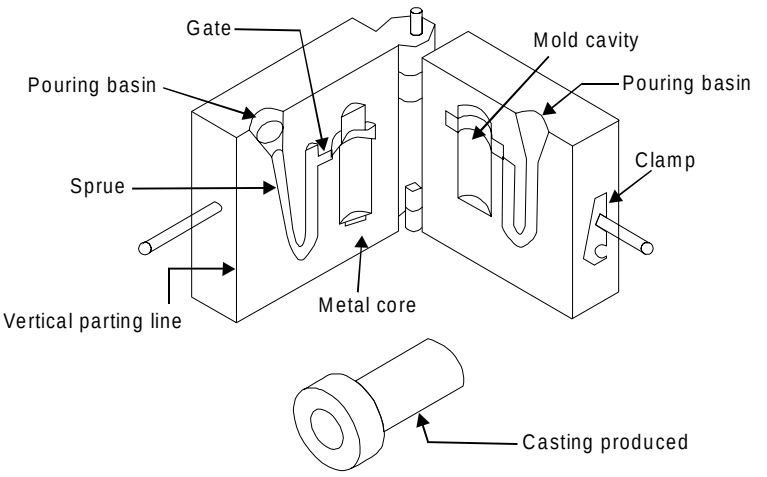


Fig. 13.2 A typical permanent mold

gravity only and no external pressure is applied to force the liquid metal into the mold cavity. However, the liquid metal solidifies under pressure of metal in the risers, etc. The metallic mold can be reused many times before it is discarded or rebuilt. These molds are made of dense, fine grained, heat resistant cast iron, steel, bronze, anodized aluminum, graphite or other suitable refractoriness. The mold is made in two halves in order to facilitate the removal of casting from the mold. It may be designed with a vertical parting line or with a horizontal parting line as in conventional sand molds. The mold walls of a permanent mold have thickness from 15 mm to 50 mm. The thicker mold walls can remove greater amount of heat from the casting. For faster cooling, fins or projections may be provided on the outside of the permanent mold. This provides the desirable chilling effect. There are some advantages, disadvantages and application of this process which are given as under.

Advantages

(*i*) Fine and dense grained structure is achieved in the casting.

(*ii*) No blow holes exist in castings produced by this method.

(*iii*) The process is economical for mass production.

(*iv*) Because of rapid rate of cooling, the castings possess fine grain structure.

(*v*) Close dimensional tolerance or job accuracy is possible to achieve on the cast product.

(*vi*) Good surface finish and surface details are obtained.

(*vii*) Casting defects observed in sand castings are eliminated.

(*viii*) Fast rate of production can be attained.

(*ix*) The process requires less labor.

Disadvantages

(*i*) The cost of metallic mold is higher than the sand mold. The process is impractical for large castings.

(*ii*) The surface of casting becomes hard due to chilling effect.

(*iii*) Refractoriness of the high melting point alloys.

Applications

(*i*) This method is suitable for small and medium sized casting such as carburetor bodies, oil pump bodies, connecting rods, pistons etc.

(*ii*) It is widely suitable for non-ferrous casting.

13.3 SLUSH CASTING

Slush casting is an extension of permanent mold casting or metallic mold casting. It is used widely for production of hollow casting without the use of core. The process is similar to metallic mold casting only with the difference that mold is allowed to open at an early stage (only when a predetermined amount of molten metal has solidified up to some thickness) and some un-solidified molten metal fall down leaving hollowness in the cast object. The process finds wide applications in production of articles namely toys, novelties, statutes, ornaments, lighting fixtures and other articles having hollowness inside the cast product.

13.4 PRESSURE DIE CASTING

Unlike permanent mold or gravity die casting, molten metal is forced into metallic mold or die under pressure in pressure die casting. The pressure is generally created by compressed air or hydraulically means. The pressure varies from 70 to 5000 kg/cm^2 and is maintained while the casting solidifies. The application of high pressure is associated with the high velocity with which the liquid metal is injected into the die to provide a unique capacity for the production of intricate components at a relatively low cost. This process is called simply die casting in USA. The die casting machine should be properly designed to hold and operate a die under pressure smoothly. There are two general types of molten metal ejection mechanisms adopted in die casting set ups which are:

(*i*) Hot chamber type
  (*a*) Gooseneck or air injection management
  (*b*) Submerged plunger management
(*ii*) Cold chamber type

Die casting is widely used for mass production and is most suitable for non-ferrous metals and al1oys of low fusion temperature. The casting process is economic and rapid. The surface achieved in casting is so smooth that it does not require any finishing operation. The material is dense and homogeneous and has no possibility of sand inclusions or other cast impurities. Uniform thickness on castings can also be maintained.

The principal base metals most commonly employed in the casting are zinc, aluminum, and copper, magnesium, lead and tin. Depending upon the melting point temperature of alloys and their suitability for the die casting, they are classified as high melting point (above 540°C) and low melting point (below 500°C) alloys. Under low category involves zinc, tin and lead base alloys. Under high temperature category aluminum and copper base alloys are involved.

There are four main types of die-casting machine which are given as under.

1. Hot chamber die casting machine
2. Cold chamber die casting machine.
3. Air blown or goose neck type machine
4. Vacuum die-casting machine

Some commonly used die casting processes are discussed as under.

Hot chamber die-casting

Hot chamber die-casting machine is the oldest of die-casting machines which is simplest to operate. It can produce about 60 or more castings of up to 20 kg each per hour and several hundred castings per hour for single impression castings weighing a few grams. The melting unit of setup comprises of an integral part of the process. The molten metal possesses nominal amount of superheat and, therefore, less pressure is needed to force the liquid metal into the die. This process may be of gooseneck or air-injection type or submerged plunger type-air blown or goose neck type machine is shown as in Fig. 13.3. It is capable of performing the following functions:

(*i*) Holding two die halves finally together.
(*ii*) Closing the die.
(*iii*) Injecting molten metal into die.

(*iv*) Opening the die.

(*v*) Ejecting the casting out of the die.

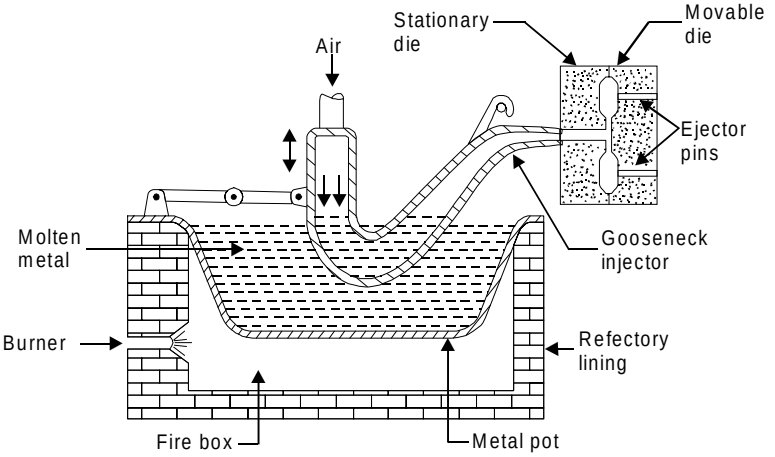


Fig. 13.3 Air blown or goose neck type die casting setup

A die casting machine consists of four basic elements namely frame, source of molten metal and molten metal transfer mechanism, die-casting dies, and metal injection mechanism. It is a simple machine as regards its construction and operation. A cast iron gooseneck is so pivoted in the setup that it can be dipped beneath the surface of the molten metal to receive the same when needed. The molten metal fills the cylindrical portion and the curved passageways of the gooseneck. Gooseneck is then raised and connected to an airline which supplies pressure to force the molten metal into the closed die. Air pressure is required for injecting metal into the die is of the order of 30 to 45 kg./cm^2. The two mold halves are securely clamped together before pouring. Simple mechanical clamps of latches and toggle kinds are adequate for small molds. On solidification of the die cast part, the gooseneck is again dipped beneath the molten metal to receive the molten metal again for the next cycle. The die halves are opened out and the die cast part is ejected and die closes in order to receive a molten metal for producing the next casting. The cycle repeats again and again. Generally large permanent molds need pneumatic or other power clamping devices. A permanent mold casting may range in weight from a few grams to 150 kg. for aluminum. Cores for permanent molds are made up of alloy steel or dry sand. Metal cores are used when they can be easily extracted from the casting. A dry sand core or a shell core is preferred when the cavity to be cored is such that a metal core cannot possibly be withdrawn from the casting. The sprues, risers, runners, gates and vents are machined into the parting surface for one or both mold halves. The runner channels are inclined, to minimize turbulence of the incoming metal. Whenever possible, the runner should be at the thinnest area of the casting, with the risers at the top of the die above the heavy sections. On heating the mold surfaces to the required temperature, a refractory coating in the form of slurry is sprayed or brushed on to the mold cavity, riser, and gate and runner surfaces. French chalk or calcium carbonate suspended in sodium silicate binder is commonly used as a coating for aluminum and magnesium permanent mold castings. Chills are pieces of copper, brass or aluminum and are inserted into the mold's inner surface. Water passages in the mold or cooling fins made on outside the mold surface are blown by air otherwise water mist will create chilling effect. A chill is commonly used to promote directional solidification.

Cold chamber die casting

Cold chamber die casting process differs from hot chamber die casting in following respects.

1. Melting unit is generally not an integral part of the cold chamber die casting machine. Molten metal is brought and poured into die casting machine with help of ladles.
2. Molten metal poured into the cold chamber casting machine is generally at lower temperature as compared to that poured in hot chamber die casting machine.
3. For this reasoning, a cold chamber die casting process has to be made use of pressure much higher (of the order of 200 to 2000 kgf/cm^2) than those applied in hot chamber process.
4. High pressure tends to increase the fluidity of molten metal possessing relatively lower temperature.
5. Lower temperature of molten metal accompanied with higher injection pressure with produce castings of dense structure sustained dimensional accuracy and free from blow-holes.
6. Die components experience less thermal stresses due to lower temperature of molten metal. However, the dies are often required to be made stronger in order to bear higher pressures.

There are some advantages, disadvantages and application of this process which are given as under.

Advantages

1. It is very quick process
2. It is used for mass production
3. castings produced by this process are greatly improved surface finish
4. Thin section (0.5 mm Zn, 0.8 mm Al and 0.7 mm Mg) can be easily casted
5. Good tolerances
6. Well defined and distinct surface
7. Less nos. of rejections
8. Cost of production is less
9. Process require less space
10. Very economic process
11. Life of die is long
12. All casting has same size and shape.

Disadvantages

1. Cost of die is high.
2. Only thin casting can be produced.
3. Special skill is required.
4. Unless special precautions are adopted for evaluation of air from die-cavity some air is always entrapped in castings causing porosity.
5. It is not suitable for low production.

Applications

1. Carburetor bodies
2. Hydraulic brake cylinders
3. Refrigeration castings
4. Washing machine
5. Connecting rods and automotive pistons
6. Oil pump bodies
7. Gears and gear covers
8. Aircraft and missile castings, and
9. Typewriter segments

13.5 ADVANTAGES OF DIE CASTING OVER SAND CASTING

1. Die casting requires less floor space in comparison to sand casting.
2. It helps in providing precision dimensional control with a subsequent reduction in machining cost.
3. It provides greater improved surface finish.
4. Thin section of complex shape can be produced in die casting.
5. More true shape can be produced with close tolerance in die casting.
6. Castings produced by die casting are usually less defective.
7. It produces more sound casting than sand casting.
8. It is very quick process.
9. Its rate of production is high as much as 800 casting / hour.

13.6 COMPARISON BETWEEN PERMANENT MOLD CASTING AND DIE CASTING

The comparison between permanent mold castings and die casting given as under in Table 13.1.

Table 13.1 Comparison between Permanent Mold Castings and Die Casting

S.No.	Permanent Mold Castings	Die Casting
1.	Permanent mold casting are less costly	Die casting dies are costly
2.	It requires some more floor area in comparison to die casting	It requires less floor area.
3.	It gives good surface finishing	It gives very fine surface finishing
4.	It requires less skill	It requires skill in maintenance of die or mold
5.	Production rate is good	Production rate is very high
6.	It has high dimensional accuracies	It also have very high dimensional accuracies

7.	This is suitable for small medium sized non-ferrous	There is a limited scope of non- ferrous alloys and it is used for small sizes of castings
8.	Initial cost is high hence it is used for large production	Initial cost is also high hence used for large production
9.	Several defects like stress, surface hardness may be produced due to surface chilling effect	This phenomenon may also occur in this case.

13.7 SHELL MOLD CASTING

Shell mold casting process is recent invention in casting techniques for mass production and smooth surface finish. It was originated in Germany during Second World War. It is also called as Carning or C process. It consists of making a mold that possesses two or more thin shells (shell line parts, which are moderately hard and smooth with a texture consisting of thermosetting resin bonded sands. The shells are 0.3 to 0.6 mm thick and can be handled and stored. Shell molds are made so that machining parts fit together-easily. They are held using clamps or adhesive and metal is poured either in a vertical or horizontal position. They are supported using rocks or mass of bulky permeable material. Thermosetting resin, dry powder and sand are mixed thoroughly in a muller.

Complete shell molding casting processes is carried in four stages as shown in Fig. 13.4. In this process a pattern is placed on a metal plate and it is then coated with a mixture of fine sand and Phenol-resin (20:1). The pattern is heated first and silicon grease is then sprayed on the heated metal pattern for easy separation. The pattern is heated to 205 to 230°C and covered with resin bounded sand. After 30 seconds, a hard layer of sand is formed over pattern. Pattern and shell are heated and treated in an oven at 315°C for 60 secs.,

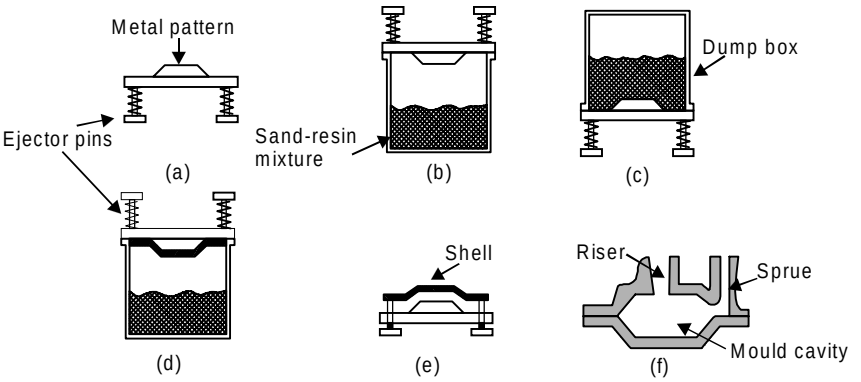


Fig. 13.4 Shell mold casting process

Phenol resin is allowed to set to a specific thickness. So the layer of about 4 to 10 mm in thickness is stuck on the pattern and the loose material is then removed from the pattern. Then shell is ready to strip from the pattern. A plate pattern is made in two or more pieces and similarly core is made by same technique. The shells are clamped and usually embedded in gravel, coarse sand or metal shot. Then mold is ready for pouring. The shell so formed has the shape of pattern formed of cavity or projection in the shell. In case of unsymmetrical shapes, two patterns are prepared so that two shell are produced which are joined to form proper cavity. Internal cavity can be formed by placing a core. Hot pattern and box is

containing a mixture of sand and resin. Pattern and box inverted and kept in this position for some time. Now box and pattern are brought to original position. A shell of resin-bonded sand sticks to the pattern and the rest falls. Shell separates from the pattern with the help of ejector pins. It is a suitable process for casting thin walled articles. The cast shapes are uniform and their dimensions are within close limit of tolerance ± 0.002 mm and it is suitable for precise duplication of exact parts. It has various advantages which are as follows. There are some advantages and disadvantages of this process which are given as under.

Advantages

The main advantages of shell molding are:

(*i*) Very suitable for thin sections like petrol engine cylinder.
(*ii*) Excellent surface finish.
(*iii*) Good dimensional accuracy of order of 0.002 to 0.003 mm.
(*iv*) Negligible machining and cleaning cost.
(*v*) Occupies less floor space.
(*vi*) Skill-ness required is less.
(*vii*) Molds can be stored until required.
(*viii*) Better quality of casting assured.
(*ix*) Mass production.

Disadvantages

(*i*) Initial cost is high.
(*ii*) Specialized equipment is required.
(*iii*) Resin binder is an expensive material.
(*iv*) Limited for small size.
(*v*) Future of shell molding process is very bright.

Applications

(*i*) Suitable for production of casting made up of alloys of Al, Cu and ferrous metals
(*ii*) Bushing
(*iii*) Valves bodies
(*iv*) Rocker arms
(*v*) Bearing caps
(*vi*) Brackets
(*vii*) Gears

13.8 CENTRIFUGAL CASTING

In centrifugal casting process, molten metal is poured into a revolving mold and allowed to solidify molten metal by pressure of centrifugal force. It is employed for mass production of circular casting as the castings produced by this process are free from impurities. Due to centrifugal force, the castings produced will be of high density type and of good strength. The castings produced promote directional solidification as the colder metal (less temperature molten metal) is thrown to outside of casting and molten metal near the axis or rotation. The cylindrical parts and pipes for handling gases are most adoptable to this process. Centrifugal casting processes are mainly of three types which are discussed as under.

(1) True centrifugal casting
(2) Semi-centrifugal casting and
(3) Centrifuged casting

True Centriugal Casting

In true centrifugal casting process, the axis of rotation of mold can be horizontal, vertical or inclined. Usually it is horizontal. The most commonly articles which are produced by this process are cast iron pipes, liners, bushes and cylinder barrels. This process does not require any core. Also no gates and risers are used. Generally pipes are made by the method of the centrifugal casting. The two processes namely De Lavaud casting process and Moore casting process are commonly used in true centrifugal casting. The same are discussed as under:

De Levaud Casting Process

Fig 13.5 shows the essential components of De Levaud type true centrifugal casting process. The article produced by this process is shown in Fig 13.6. In this process, metal molds prove to be economical when large numbers of castings are produced. This process makes use of metal mold. The process setup contains an accurately machined metal mold or die surrounded by cooling water. The machine is mounted on wheels and it can be move lengthwise on a straight on a slightly inclined track. At one end of the track there is a ladle containing proper quantities of molten metal which flows a long pouring spout initially inserted to the extremity of the mold. As pouring proceeds the rotating mold, in the casting machine is moved slowly down the track so that the metal is laid progressively along the length of the mold wall flowing a helical path. The control is being achieved by synchronizing the rate of pouring, mold travel and speed of mold rotation. After completion of pouring the machine will be at the lower end of its track with the mold that rotating continuously till the molten metal has solidified in form of a pipe. The solidified casting in form of pipe is extracted from the metal mold by inserting a pipe puller which expands as it is pulled.

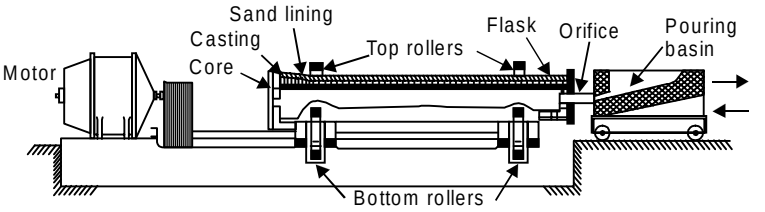


Fig. 13.5 De Levaud type true entrifugal casting process.

Moore Casting System

Moore casting system for small production of large cast iron pipes employs a ram and dried sand lining in conjunction with end pouring. As the mold rotates, it does not move lengthwise rather its one end can be raised up or lowered to facilitate progressive liquid metal. Initially one end of the mold is raised as that mold axis gets inclined. As the pouring starts and continues, the end is gradually lowered till the mold is horizontal and when the pouring stops. At this stage, the speed of mold rotation is increased and maintained till the casting is solidified. Finally, the mold rotation is stopped and the casting is extracted from the mold.

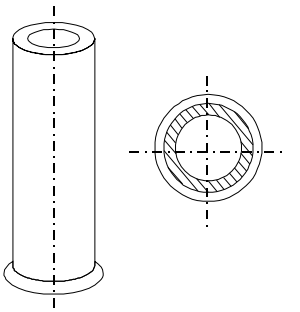


Fig. 13.6 Article produced by true centrifugal casting process

Semi-Centrifugal Casting

It is similar to true centrifugal casting but only with a difference that a central core is used to form the inner surface. Semi- centrifugal casting setup is shown in Fig. 13.7. This casting process is generally used for articles which are more complicated than those possible in true centrifugal casting, but are axi-symmetric in nature. A particular shape of the casting is produced by mold and core and not by centrifugal force. The centrifugal force aids proper feeding and helps in producing the castings free from porosity. The article produced by this process is shown in Fig. 13.8. Symmetrical objects namely wheel having arms like flywheel, gears and back wheels are produced by this process.

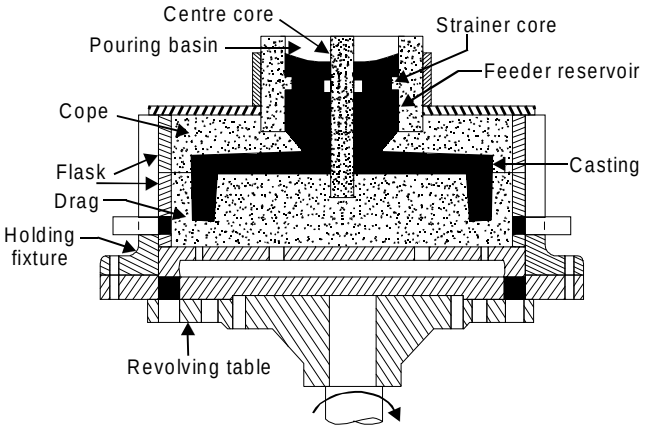


Fig. 13.7 Semi-centrifugal casting setup

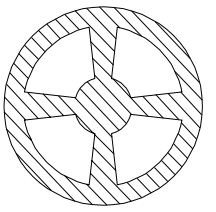


Fig. 13.8 Article produced by semi-centrifugal casting process

Centrifuging Casting

Centrifuging casting setup is shown in Fig. 13.9. This casting process is generally used for producing non-symmetrical small castings having intricate details. A number of such small jobs are joined together by means of a common radial runner with a central sprue on a table which is possible in a vertical direction of mold rotation. The sample article produced by this process is depicted in Fig. 13.10.

13.9 CONTINNOUS CASTING

In this process the molten metal is continuously poured in to a mold cavity around which a facility for quick cooling the molten metal to the point of solidification. The solidified metal is then continuously extracted from the mold at predetermined rate. This process is classified into two categories namely Asarco and Reciprocating. In reciprocating process, molten metal is poured into a holding furnace. At the bottom of this furnace, there is a valve by which the quantity of flow can be changed. The molten metal is poured into the mold at a uniform speed. The water cooled mold is reciprocated up and down. The solidified portion of the casting is withdrawn by the rolls at a constant speed. The movement of the rolls and the reciprocating motion of the rolls are fully mechanized and properly controlled by means of cams and follower arrangements.

Advantages of Continuous Casting

(*i*) The process is cheaper than rolling

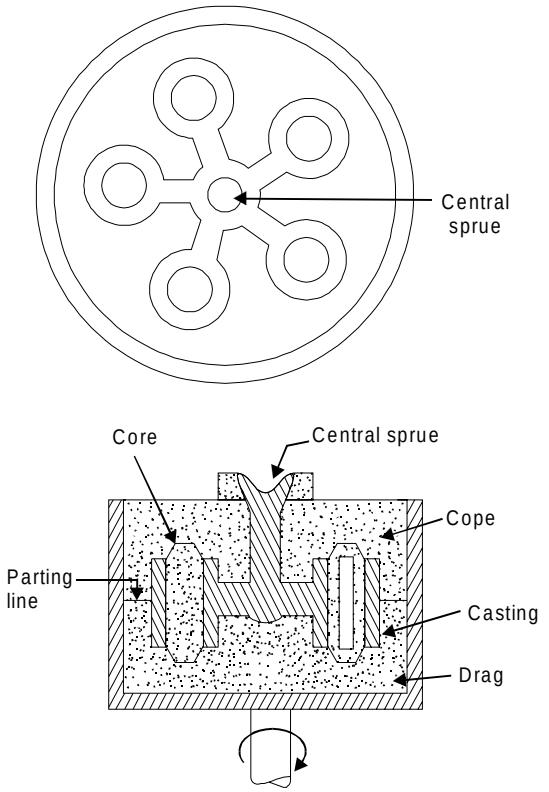


Fig. 13.9 Centrifuging casting setup

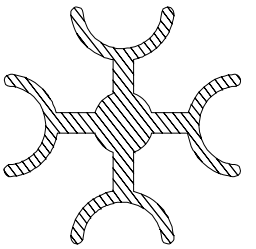


Fig. 13.10 Article produced by centrifuging casting process

(*ii*) 100% casting yield.

(*iii*) The process can be easily mechanized and thus unit labor cost is less.

(*iv*) Casting surfaces are better.

(*v*) Grain size and structure of the casting can be easily controlled.

Applications of Continuous Casting

(*i*) It is used for casting materials such as brass, bronzes, zinc, copper, aluminium and its alloys, magnesium, carbon and alloys etc.

(*ii*) Production of blooms, billets, slabs, sheets, copper bar etc.

(*iii*) It can produce any shape of uniform cross-section such as round, rectangular, square, hexagonal, fluted or gear toothed etc.

13.10 PROBABLE CAUSES AND SUGGESTED REMEDIES OF VARIOUS CASTING DEFECTS

The probable causes and suggested remedies of various casting defects is given in Table 13.1.

Table 13.1: Probable Causes and Suggested Remedies of Various Casting Defects

S.No.	Name of Casting Defect	Probable Causes	Suggested Remedies
1.	Blow holes	1. Excess moisture content in molding sand.	1. Control of moisture content.
		2. Rust and moisture on Chills, chaplets and inserts	2. Use of rust free chills, chaplet and clean inserts.
		3. Cores not sufficiently baked.	3. Bake cores properly.
		4. Excessive use of organic binders.	4. Ram the mold s less hard.
		5. Molds not adequately vented.	5. Provide adequate venting in
		6. Molds not adequately vented.	mold and cores
		7. Molds rammed very hard.	
2.	Shrinkage	1. Faulty gating and risering system.	1. Ensure proper directional solidification by modifying gating, risering and chilling
		2. Improper chilling.	
3.	Porosity	1. High pouring temperature.	1. Regulate pouring temperature
		2. Gas dissolved in metal charge.	2. Control metal composition.
		3. Less flux used.	3. Increase flux proportions.
		4. Molten metal not properly degassed.	4. Ensure effective degassing.
		5. Slow solidification of casting.	5. Modify gating and risering.
		6. High moisture and low permeability in mold.	6. Reduce moisture and increase permeability of mold.
4.	Misruns	1. Lack of fluidity ill molten metal.	1. Adjust proper pouring temperature.
		2. Faulty design.	2. Modify design.
		3. Faulty gating.	3. Modify gating system.
5.	Hot Tears	1. Lack of collapsibility of core.	1. Improve core collapsibility.
		2. Lack of collapsibility of mold	2. Improve mold collapsibility.
		3. Faulty design.	3. Modify casting design.
		4. Hard Ramming of mold.	4. Provide softer ramming.
6.	Metal	1. Large grain size and used.	1. Use sand having finer grain size.
	penetration	2. Soft ramming of mold.	2. Provide hard ramming.
		3. Molding sand or core has low strength.	3. Suitably adjust pouring temperature.
		4. Molding sand or core has high permeability.	
		5. Pouring temperature of metal too high.	
7.	Cold shuts	1. Lack of fluidity in molten metal.	1. Adjust proper pouring temperature.
		2. Faulty design.	2. Modify design.
		3. Faulty gating.	3. Modify gating system
8.	Cuts and	1. Low strength of mold and core.	1. Improve mold and core strength.
	washes	2. Lack of binders in facing and core stand.	2. Add more binders to facing and core sand.
		3. Faulty gating.	3. Improve gating

9.	Inclusions	1. Faulty gating.	1. Modify gating system
		2. Faulty pouring.	2. Improve pouring to minimize turbulence.
		3. Inferior molding or core sand.	3. Use of superior sand of good strength.
		4. Soft ramming of mold.	4. Provide hard, ramming.
		5. Rough handling of mold and core.	
10.	Fusion	1. Low refractoriness in molding sand	1. Improve refractoriness of sand.
		2. Faulty gating.	2. Modify gating system.
		3. Too high pouring temperature of metal.	3. Use lower pouring temperature.
		4. Poor facing sand.	4. Improve quality of facing sand.
11.	Drops	1. Low green strength in molding sand and core.	1. Increase green strength of sand mold.
		2. Too soft ramming.	2. Provide harder ramming.
		3. Inadequate reinforcement of sand and core projections	3. Provide adequate reinforcement to sand projections and cope by using nails and gaggers.
12.	Shot Metal	1. Too low pouring temperature.	1. Use proper pouring temperature.
		2. Excess sulphur content in metal.	2. Reduce sulphur content.
		3. Faulty gating.	3. Modify gating of system.
		4. High moisture content in molding sand.	
13.	Shift	1. Worn-out or bent clamping pins.	1. Repair or replace the pins, for removing defect.
		2. Misalignment of two halves of pattern.	2. Repair or replace dowels which cause misalignment.
		3. Improper support of core.	3. Provide adequate support to core.
		4. Improper location of core.	4. Increase strength of both mold
		5. Faulty core boxes.	and core
		6. Insufficient strength of molding sand and core.	
14.	Crushes	1. Defective core boxes producing over-sized cores.	1. Repair or replace the pins, for removing defect.
		2. Worn out core prints on patterns producing under sized seats for cores in the mold.	2. Repair or replace dowels which cause misalignment.
		3. Careless assembly of cores in the mold	3. Provide adequate support to core.
			4. Increase strength of both mold and core.
15.	Rat-tails or Buckles	1. Continuous large flat surfaces on casting.	1. Break continuity of large flat groves and depressions
		2. Excessive mold hardness.	2. Reduce mold hardness.
		3. Lack of combustible additives in molding sand.	3. Add combustible additives to sand.

16.	Swells	1. Too soft ramming of mold.	1. Provide hard ramming.
		2. Low strength of mold and core	2. Increase strength of both mold
		3. Mold not properly supported.	and core.
17.	Hard Spot	1. Faulty metal composition.	1. Suitably charge metal composition.
		2. Faulty casting design.	2. Modify casting design.
18.	Run out, Fins	1. Faulty molding.	1. Improving molding technique.
	and Fash	2. Defective molding boxes.	2. Change the defective molding boxes.
			3. Keep weights on mold boxes.
19.	Spongings	1. Availability of dirt and swarf held in molten metal.	1. Remove dirt swarf held in molten metal.
		2. Improper skimming.	2. Skimming should be perfect.
		3. Because of more impurities in molten metal	3. Fewer impurities in molten metal should be there.
20.	Warpage	1. Continuous large flat surfaces on castings indicating a poor design.	1. Follow principle of sufficient directional solidification
		2. No directional solidification of casting.	2. Make good casting design

13.11 PLASTICS MOLDING PROCESSES

There are various methods of producing components from the plastics materials which are supplied in the granular, powder and other forms. Various plastics molding processes are:

1. Compression Molding.
2. Transfer Molding
3. Injection Molding.
4. Blow Molding.
5. Extrusion Molding
6. Calendaring.
7. Thermoforming.
8. Casting

Two major processes from the above are discussed as under.

13.11.1 Injection die Molding

In this process, thermoplastic materials soften when heated and re-harden when cooled. No chemical change takes place during heating and cooling. Fig. 13.11 illustrates the injection molding process. The process involves granular molding material is loaded into a hopper from where it is metered out in a heating cylinder by a feeding device. The exact amount of material is delivered to the cylinder which is required to fill the mold completely. The injection ram pushes the material into a heating cylinder and doing so pushing bushes a small amount of heated material out of other end of cylinder through the nozzle and screw bushing and into cavities of the closed mold. The metal cooled in rigid state in the mold. Then mold is opened and piece is ejected out material heating temperature is usually between 180°-280°C. Mold is cooled in order to cool the mold articles. Automatic devices are commercially available to maintain mold temperature at required level. Injection molding is generally limited to forming thermoplastic materials, but equipment is available for converting the machines for molding thermosetting plastics and compounds of rubber.

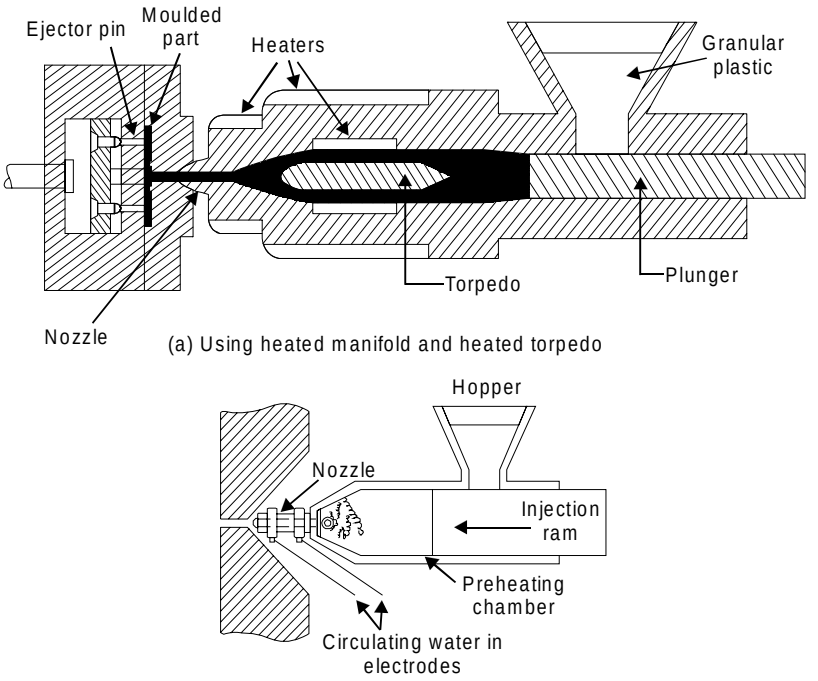


Fig. 13.11 Typical injection molding

13.11.2 Extrusion Molding

Generally all thermo plastic materials are highly suitable for extrusion in to various shapes such as rods, tubes, sheets, film, pipes and ropes. Thermosetting plastic is not suitable for extrusion molding. In this process the powder polymer or monomer is received through hopper and is fed in to the heated chamber by a rotating screw along a cylindrical chamber. The rotating screw carries the plastic powder forward and forces it through the heated orifice of the die. As the thermoplastic powder reaches towards the die, it gets heated up and melts. It is then forced through the die opening of desired shape as shown in the sectional view of the extrusion molding process through Fig 13.12. On leaving the product from the die, it is cooled by water or compressed air and is finally carried by a conveyor or belt. The process is continuous and involves low initial cost.

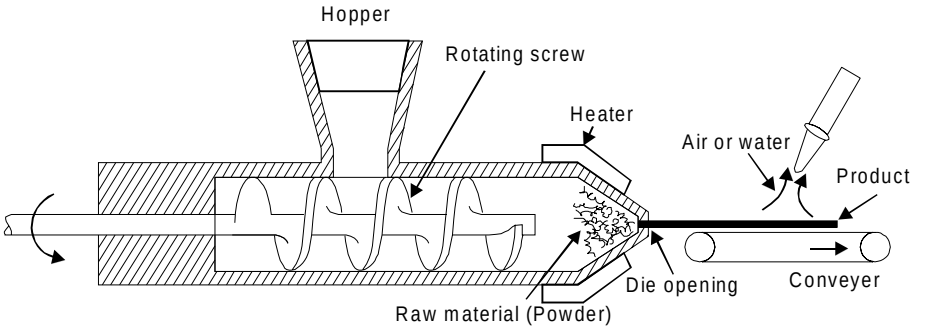


Fig. 13.12 Schematic extrusion molding

13.12 QUESTIONS

1. Describe in detail the terms 'solid zone', 'mushy zone' and 'liquid zone' used in solidification of castings. Using figures explain the term directional solidification used in castings.
2. What is "directional solidification", and what is its influence on casting quality?
3. Is directional solidification is necessary in casting? How does it help in the production of sound castings?
4. What are the controlling factors of directional solidification in casting? Name different stages through which the metal contraction takes place during the solidification of the casting?
5. Why do you prefer fabricating of metal parts by casting?
6. Define casting. What four basic steps are generally involved in making a casting?
7. What are the common factors which should be considered before designing a casting?
8. Sketch the cross-section through a permanent mold, incorporating all its principal parts. Describe its construction in detail.
9. Describe the permanent mold casting process and discuss how it differs from the other casting processes.
10. What are the common materials used for making the permanent molds?
11. Describe step by step procedure for casting using a permanent mold. What are the advantages, dis-advantages and applications of permanent mold casting?
12. What different metals and alloys are commonly cast in permanent molds?
13. What is the difference between gravity die casting and pressure die casting?
14. How are die casting machines classified? What are the common constructional features embodied in most of them?
15. Sketch and explain the construction and operation of a hot chamber die casting machine.
16. How does a cold chamber die casting machine differ from a hot chamber machine? Explain the working of a cold chamber machine with the help of a diagram.
17. Make a neat sketch to explain the principal parts of an air blown or goose neck type machine. How does it differ from a hot chamber die casting machine. Discuss their relative advantages, disadvantages and applications.
18. What is a vacuum die-casting machine? How is the vacuum applied to hot and cold chamber machines to evacuate the entrapped air completely. What is the main advantage of this type of machine?
19. Specify features required to be embodied in a successful design of a die-casting die.
20. Describe the various alloys commonly cast through pressure die-casting.
21. What are the general advantages, disadvantages applications of die casting?
22. How does a cold chamber die casting machine differ from a hot chamber die casting machine?
23. Make neat sketch and explain the construction and operation of a hot chamber die casting machine.
24. Make neat sketch and explain the construction and operation of a cold chamber die casting machine.
25. Explain the various steps involved in the investment casting of metals.
26. What is investment casting? What are the main materials used for making the investment pattern?
27. Describe the complete step by step procedure of investment casting. What are the main advantages and disadvantages of investment casting?

28. Describe briefly the shell casting process using neat sketches. State its advantages, disadvantages and generation applications
29. Describe continuous casting process and discuss the important metallurgical features of the billets produced by these methods.
30. Explain with the help of a neat sketch, the process of centrifugal casting.
31. What do you understand from centrifugal casting?
32. How are the centrifugal casting methods classified?
33. With the help of a neat diagram describe the process of true centrifugal casting. How can this method be used for production of pipes?
34. Illustrate and describe the process of semi-centrifugal casting.
35. What is centrifuging casting?. Describe the process, stating its differences with other centrifugal casting methods.
36. What are the advantages and disadvantages of true centrifugal casting?
37. Which materials are commonly used for making the molds for centrifugal casting?
38. Explain the difference with the help of sketches between true centrifugal casting, semi-centrifugal casting and centrifuge casting.
39. What is continuous casting? Name the various processes of continuous casting you know. Describe in detail the reciprocating process of continuous casting.
40. How will you select the vertical and inclined axes of rotation in true centrifugal casting.
41. Write short notes on the following:
    (*i*) Slush casting
    (*ii*) Pressed casting
    (*iii*) De Lavaud process for centrifugal casting
    (*iv*) Moore sand spun process for centrifugal casting.

42 What are the general rules and principles to be followed in designing a casting?

43 What do you understand by foundry mechanization? Explain in brief.

44 What are the advantages of mechanization of foundry?

45 Describe the various units for which mechanization can be easily adopted.

46 What are the main factors which are responsible for producing defects in the castings?

47 Name the various defects which occur in sand castings and state their probable causes and remedies?

48 List the defects generally occurring from the following, stating the precautions necessary to prevent them:
    (*i*) Improper pouring technique, (*ii*) Use of defective gating system
    (*iii*) Poor or defective cores, (*iv*) High moisture content in sand.

49. Discuss briefly the causes and remedies of the following casting defects:
    (*i*) Blow holes, (*ii*) Porosity, (*iii*) Hot tears
    (*iv*) Shrinkage cavities, (*v*) Scabs, and (*vi*) Gas porosity

50. Write short notes on the following casting defects:
    (*i*) Sand inclusions, (*ii*) Cuts and washes, (*iii*) Misrun and cold shuts,
    (*iv*) Honey combing, (*v*) Metal penetration, (*vi*) Drops,
    (*vii*) Warpage and (*vii*) blow holes

51. Explain the causes and remedies of the following casting defects:
    (*i*) Fins
    (*ii*) Shot metal
    (*iii*) Shifts
    (*iv*) Hard spots
    (*v*) Run out
    (*vi*) Rattails or buckles
    (*vii*) Fusion
    (*viii*) Swells
    (*ix*) Crushes
52. What are the various operations generally required to be performed after shake out for cleaning the castings?
53. Explain the various methods used for removal of gates and risers etc.
54. What are the common methods used for cleaning the surface of the casting?
55. Why are the castings heat treated?
56. How do you repair the castings? Explain.
57. What do you understand from destructive and non-destructive testing methods of inspecting castings?
58. What are the various non-destructive testing methods used for inspection of castings? State their advantages and limitations:
59. Write short notes on the following inspection methods:
    (*i*) Visual inspection
    (*ii*) Pressure test
    (*iii*) Penetrate testing
    (*iv*) Radiography
    (*v*) Magnetic particle testing
    (*vi*) Ultrasonic testing.

14
CHAPTER

FORGING

14.1 INTRODUCTION

Forging is an oldest shaping process used for the producing small articles for which accuracy in size is not so important. The parts are shaped by heating them in an open fire or hearth by the blacksmith and shaping them through applying compressive forces using hammers. Thus forging is defined as the plastic deformation of metals at elevated temperatures into a predetermined size or shape using compressive forces exerted through some means of hand hammers, small power hammers, die, press or upsetting machine. It consists essentially of changing or altering the shape and section of metal by hammering at a temperature of about 980°C, at which the metal is entirely plastic and can be easily deformed or shaped under pressure. The shop in which the various forging operations are carried out is known as the smithy or smith's shop. A metal such as steel can be shaped in a cold state but the application of heat lowers the yield point and makes permanent deformation easier. Forging operation can be accomplished by hand or by a machine hammer. Forging processes may be classified into hot forging and cold forgings and each of them possesses their specific characteristics, merits, demerits and applications.

Hand forging process is also known as black-smithy work which is commonly employed for production of small articles using hammers on heated jobs. It is a manual controlled process even though some machinery such as power hammers can also be sometimes used. Black-smithy is, therefore, a process by which metal may be heated and shaped to its requirements by the use of blacksmith tools either by hand or power hammer. In smithy small parts are shaped by heating them in an open fire or hearth. Shaping is done under hand control using hand tools. This work is done in a smithy shop. In smith forging or hand forging open face dies are used and the hammering on the heated metal is done by hand to get the desired shape by judgment.

Forging by machine involves the use of forging dies and is generally employed for mass-production of accurate articles. In drop forging, closed impression dies are used and there is drastic flow of metal in the dies due to repeated blow or impact which compels the plastic metal to conform to the shape of the dies. The final shape of the product from raw material is achieved in a number of steps. There are some advantages, disadvantages and applications of forging operations which are given as under.

Advantages of forging

Some common advantages of forging are given as under.

1. Forged parts possess high ductility and offers great resistance to impact and fatigue loads.
2. Forging refines the structure of the metal.
3. It results in considerable saving in time, labor and material as compared to the production of similar item by cutting from a solid stock and then shaping it.
4. Forging distorts the previously created unidirectional fiber as created by rolling and increases the strength by setting the direction of grains.
5. Because of intense working, flaws are rarely found, so have good reliability.
6. The reasonable degree of accuracy may be obtained in forging operation.
7. The forged parts can be easily welded.

Disadvantages of forging

Few dis-advantages of forging are given as under.

1. Rapid oxidation in forging of metal surface at high temperature results in scaling which wears the dies.
2. The close tolerances in forging operations are difficult to maintain.
3. Forging is limited to simple shapes and has limitation for parts having undercuts etc.
4. Some materials are not readily worked by forging.
5. The initial cost of forging dies and the cost of their maintenance is high.
6. The metals gets cracked or distorted if worked below a specified temperature limit.
7. The maintenance cost of forging dies is also very high.

Applications of forging

Almost all metals and alloys can be forged. The low and medium carbon steels are readily hot forged without difficulty, but the high-carbon and alloy steels are more difficult to forge and require greater care. Forging is generally carried out on carbon alloy steels, wrought iron, copper-base alloys, alumunium alloys, and magnesium alloys. Stainless steels, nickel-based super-alloys, and titanium are forged especially for aerospace uses.

Producing of crank shaft of alloy steel is a good example which is produced by forging. Forging processes are among the most important manufacturing techniques utilized widely in manufacturing of small tools, rail-road equipments, automobiles and trucks and components of aeroplane industries. These processes are also extensively used in the manufacturing of the parts of tractors, shipbuilding, cycle industries, railroad components, agricultural machinery etc.

14.2 FORGEABILITY

The ease with which forging is done is called forgeability. The forgeability of a material can also be defined as the capacity of a material to undergo deformation under compression without rupture. Forgeability increases with temperature up to a point at which a second

phase, e.g., from ferrite to austenite in steel, appears or if grain growth becomes excessive. The basic lattice structure of metals and their alloys seems to be a good index to their relative forgeability. Certain mechanical properties are also influenced by forgeability. Metals which have low ductility have reduced forgeability at higher strain rate whereas highly ductile metals are not so strongly affected by increasing strain rates. The pure metals have good malleability and thus good forging properties. The metals having high ductility at cold working temperature possesses good forgeability.

Cast parts, made up of cast iron are brittle, and weak in tension, though they are strong in compression. Such parts made using cast iron tend to need to be bulky and are used where they will not be subjected to high stresses. Typical examples are machine bases, cylinder blocks, gear-box housings etc. Besides the above factors, cost is another major consideration in deciding whether to cast a component or to forge it. An I.C. engine connecting rod is a very good example of where a forging will save machining time and material, whereas the cylinder block of the same engine would be very expensive if produced by any process other than casting. Another good point associated with casting is that big or small complex shapes can easily be cast. Small parts can directly be machined out from regular section materials economically. A part machined out from the rolled steel stock definitely possesses better mechanical properties than a conventionally cast part. Sometimes the shape and size of a part would mean removing a large amount of material by machining, it is sometimes more economical to forge the part, thereby reducing the machining time and the amount of material required.

The main alloys for cold forging or hot forging are most aluminium and copper alloys, including the relatively pure metals. Carbon steels with 0.25 % carbon or less are readily hot forged or cold-headed. High carbon and high alloy steels are almost always hot forged. Magnesium possessing hexagonal close packed (HCP) structure has little ductility at room temperature but is readily hot forged. Aluminium alloys are forged between 385°C and 455°C or about 400°C below the temperature of solidification. Aluminium alloys do not form scale during hot forging operations, die life is thus excellent. Copper and brasses with 30% or less zinc have excellent forgeability in cold working operations. High zinc brasses can be cold forged to a limited extent but are excellent hot forging alloys. Magnesium alloys are forged on presses at temperature above 400°C. At higher temperatures, magnesium must be protected from oxidation or ignition by an inert atmosphere of sulphur dioxide.

14.3 FORGABLE MATERIALS

Two-phase and multi-phase materials are deformable if they meet certain minimum requirements. The requirement of wrought metals is satisfied by all pure metals with sufficient number of slip planes and also by most of the solid solution alloys of the same metal. Wrought alloys must possess a minimum ductility that the desired shape should possess. To be a forgeable metal, it should possess the required ductility. Ductility refers to the capacity of a material to undergo deformation under tension without rupture. Forging jobs call for materials that should possess a property described as ductility that is, the ability to sustain substantial high plastic deformation without fracture even in the presence of tensile stresses. If failure occurs during forging, it is due to the mechanism of ductile fracture and is induced by tensile stresses. A material of a given ductility may fail very differently in various processes, depending on the deforming conditions imposed

on it. Forgeable metals are purchased as hot-rolled bars or billets with round or rectangular cross the sections. Forgeable materials should possess the required ductility and proper strength. Some forgeable metals are given as under in order of increasing forging difficulty.

1. Aluminium alloys
2. Magnesium alloys
3. Copper alloys.
4. Carbon and low alloy steels
5. Martensitic stainless steels
6. Austenitic stainless steels
7. Nickel alloys
8. Titanium alloys
9. Columbium alloys
10. Tantalum alloys
11. Molybdenum alloys
12. Tungsten alloys
13. Beryllium.

14.4 HEATING DEVICES

Forgeable metals are heated either in a hearth or in a furnace. The hearths are widely used for heating the metals for carrying out hand forging operations. Furnaces are also commonly used for heating metals for heavy forging. The forging job is always heated to the correct forging temperature in a hearth (Fig. 14.1) or in a furnace (Fig. 14.2) located near the forging arrangements. Gas, oil or electric-resistance furnaces or induction heating classified as open or closed hearths can be used. Gas and oil are economical, easily controlled and mostly used as fuels. The formation of scale, due to the heating process especially on steel creates problems in forging. A non-oxidizing atmosphere should, therefore, be maintained for surface protection. Special gas-fired furnaces have been developed to reduce scaling to minimum. Electric heating is the most modern answer to tackle scaling and it heats the stock more uniformly also. In some cases, coal and anthracite, charcoal containing no sulphur and practically no ash are the chief solid fuels used in forging furnaces. Forge furnaces are built raise temperatures up to 1350°C in their working chambers. They should be sufficiently large to allow proper combustion of the fuel, and to obtain uniform heating of the forging jobs. Each heating furnace consists of parts including firebox, working chamber, chimney, flues, re-cuperator or regenerator, and various auxiliary arrangements. Various types of furnaces are used for heating the metals and some of them are briefly described as under.

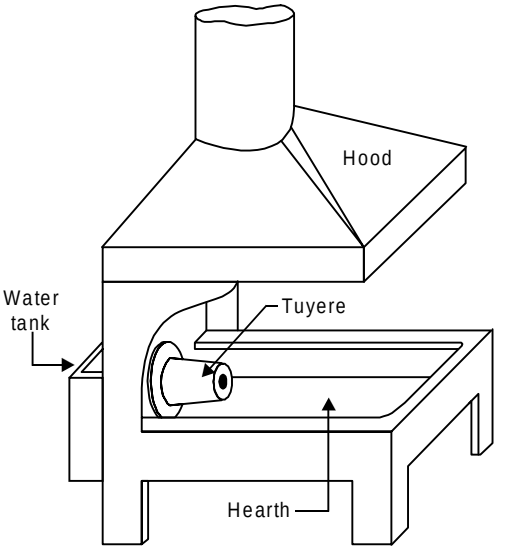


Fig. 14.1 Typical hearth

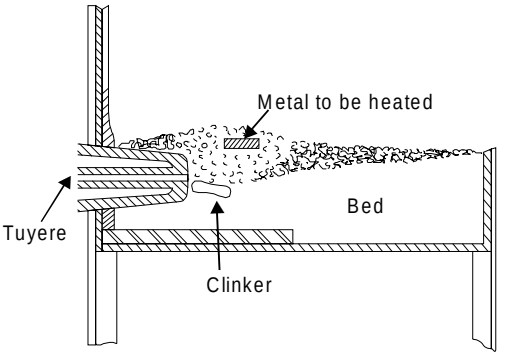


Fig. 14.2 Black smith furnace

14.4.1 Box or batch type furnaces

These furnaces are the least expensive furnaces widely used in forging shops for heating small and medium size stock. There is a great variety of design of box-type furnaces, each differing in their location of their charging doors, firing devices and method, employed for .charging their products. These furnaces are usually constructed of a rectangular steel frame, lined with insulating and refractory bricks. One or more burners for gas or oil can be provided on the sides. The job-pieces are placed side by side in the furnace using a slot through a suitable tong. It is therefore sometimes called slot type furnace.

14.4.2 Rotary-hearth furnaces

These are set to rotate slowly so that the stock is red to the correct temperature during one rotation. These can be operated by gas or oil fuels.

14.4.3 Continuous or conveyor furnaces

These furnaces are of several types and are preferred for larger stock. They have an air or oil-operated cylinder to push stock end-to-end through a narrow furnace. The pieces are charged at one end, conveyed through the furnace and moved at other end at the correct temperature for the forging work.

14.4.4 Induction furnaces

These furnaces are very popular because induction greatly decreases scale formation and can often be operated by one person. The furnace requires less maintenance than oil or gas-fired furnaces. In induction furnaces the stocks are passed through induction coils in the furnaces. Delivery to forging machine operator can be effected by slides or automatic handling equipment.

14.4.5 Resistance furnaces

These furnaces are faster than induction furnaces, and can be automated easily. In resistance heating furnace, the stock is connected to the circuit of a step-down transformer. Fixtures are also equipped along with furnace for holding different length, shape, and diameter of stock. However, the fixtures are often quite simple and can be adjusted to handle a family of parts.

14.4.6 Open fire and stock fire furnace

The fire itself plays an important part on the efficient heating of stock and it must be kept clean, free from excess dust or clinkers. Work which is laid on top of the fire will get hot underneath and remain colder on the top use it is exposed to the atmosphere, and uneven heating will result. In the same way, work which is red low in the fire but at the same time against the tuyre will become hot on one side, but will have a blast of clod air blowing against it, from the tuyre on the other side. The correct position for heating the job is in the hearth of the fire. The most common methods of firing in forging are namely open fire and stock fire which are discussed as under.

Open fire

Open fire is shown in Fig.14.3. This type of fire is highly convenient for general heating work and is made up in the hollow space in front of tuyre nozzle with coke left from the last fire, covered with green petroleum. As the fire burns away, coke from the top and sides is drawn into the centre, and its place is taken by more green coal taken from the supply maintained on the front place of the forge or taken from the outside. The jobs or work-pieces must be covered with a layer of coal, and to obtain a flame at single spot, the coal should be slightly damped with water and pressed down with a flat shovel. In the spot where the flame is desired, the coal should be loosened with a pocker. To ensure uniform heating of work on all sides, it must be turned round from time to time.

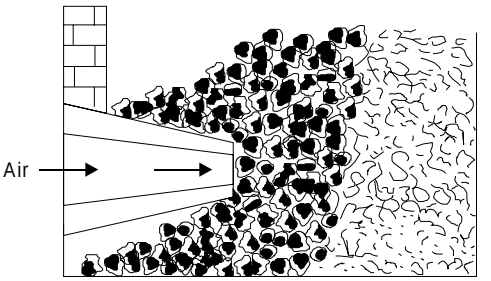


Fig. 14.3 Open fire

Stock fire

A stock fire is depicted through Fig.14.4 which is intended to last for several hours. This type of fire is commonly useful in dealing with large pieces, when a heat may have to be kept for sometime. The job or work has to be turned in all directions to ensure uniform heating of the job. Such fire is made up around a block of the desired size which is placed near the tuyer nozzle and upon which coal damped with water that is closely built into the form of a mound or "stock". Fine coal or pulverized coal is suitable for use in stock fire. The block is then withdrawn from the bed of the hearth with a turning force to prevent the stock from being broken and a tunnel is thus formed with an opening at the top. The fire is then lighted in the hollow space. From the bottom of the tunnel a small amount of coal is removed and a cavity is formed in the place in to which clinker may fall. Here the work is heated, being carefully covered with freshly coke fuel from time to time as the fire burns away.

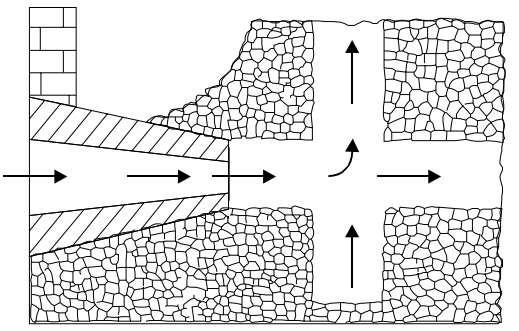


Fig. 14.4 Stock fire

14.4.7 Fuels used in forging shop

The fuels used in forging shop are classified as solid, liquid and gaseous fuels which are discussed as under.

Solid fuels

Wood, coal, anthracite, peat, charcoal, coke, pulverized fuel etc.

Liquid fuels

Crude oil, petroleum, kerosene, tar oil etc.

Gaseous fuels

Natural gas and some artificially produced gases are used generate heat.

A good fuel should have always possesses the following essential characteristic which are given as under.

1. The fuel should be able to generate the required heat.
2. It should have complete combustion.
3. It should be highly efficient.
4. It should not produce excess smoke and flying ash.
5. It should be easy to fire, cheap and easily available.

14.5 CONTROL OF HEATING DEVICES

For good control of heating devices such as hearth or forging furnace, the following points are should always be considered.

1. The nozzle pointing into the centre of the hearth is called the tuyre and is used to direct a stream of air into the burning coke. The air is supplied by centrifugal blower.
2. As the hottest part of the fire is close to the tuyre opening, therefore, the tuyre is provided with a water jacket to prevent it from burning away.
3. The hood provided at the top of hearth collects smoke, fumes etc., and directs them away from the workplace through the chimney in form of exhaust.
4. The fuel for the fire may be either black-smithing coal or coke. To light the fire, either use paper and sticks or preferably a gas poker.
5. Impurities will collect as clinker and must be removed from the bottom of the fire when the fire cools.
6. The blowers are used to control the air supply using forced draught. Regulators control the draught and the temperature of the fire.
7. Blower delivers to forge adequate supply of air at proper pressure which is very necessary for the combustion of fuel.
8. A centrifugal blower driven by an electric motor is an efficient means of air supply in forging hearth.
9. Fire tools such as rake, poker and slice are generally used to control or manage the fire and theses tools are kept nearby the side of the hearth. Rake is used to take heated workpiece out of the fire. Poker is a steel rod which is used to poke (stir) fire in the hearth.

10. The place of the metal to be heated should be placed just above the compact centre of a sufficiently large fire with additional fuel above to reduce the heat loss and atmospheric oxidation.

14.6 FORGING TEMPERATURES

A metal must be heated to a temperature at which it will possess high plastic properties to carry out the forging process. The metal work piece is heated to a proper temperature so that it gains required plastic properties before deformation, which are essential for satisfactory forging. Excessive temperatures may result in the burning of the metal. Insufficient temperatures will not introduce sufficient plasticity in the metal to shape it properly by hammering etc. Moreover, under these conditions, the cold working defects such as hardening and cracking may occur in the product.

The temperature to start the forging for soft, low carbon steels is 1,250 to 1,300°C, the temperature to finish forging is 800 to 840°C. The corresponding temperatures for high carbon and alloy steels which are hard in nature are 1100 to l140°C and 830 to 870°C. Wrought iron is best forged at a temperature little below 1,290°C. Non ferrous alloys like bronze and brass are heated to about 600 to 930°C, the aluminium and magnesium alloys to about 340 to 500°C.

Forging temperature should be proper to get good results. Excessive temperature may result in the burning of the metal, which destroys the cohesion of the metal. Insufficient temperature will not introduce sufficient plasticity in the metal. The forging operation in metal is if finished at a lower temperature, it may lead to cold hardening and cracks may develop in it. However, excessive heating of the forgeable part may result in oxidization and hence material is wasted. The temperature of heating steel for hand forging can be estimated by the color of heat and which color of the light emitted by the heated steel. For accurate determinations of forging temperatures of the heated part, the optical pyrometers are generally used.

14.7 ADVANTAGES OF FORGING IN COMPARASION TO CASTING AND MACHINING

Because of inherent improvement in the grain size and introduction of un-interrupted grain flow in the structure of finished forged component forging has the following advantages in comparison to casting and machining. Some of such advantages are given as under.

(*i*) Greater strength and toughness.

(*ii*) Reduction in weight of the finished part.

(*iii*) Saving in the material.

(*iv*) Elimination of internal defects such as cracks, porosity, blowholes, etc.

(*v*) Ability to withstand unpredictable loads during service.

(*vi*) Minimum of machine finish to be carried out on the component especially when it is forged in dies.

14.8 EFFECT OF FORGING ON METAL CHARACTERISTICS

Generally a forging material is selected based on certain desirable mechanical properties inherent in the composition and/or for those which can be developed by forging. Such properties may be one or several, such as strength, resistance to fatigue, shock or bending, good

machining characteristics, durability etc. A continuous and uninterrupted grain flow in a forged component results in higher strength and toughness. In a cast part, there is no grain flow. Cast part is having random orientation of grains so it has weak crystalline structure. In a rolled or machined component, an interrupted grain flow exists. Rolled component is having better ductility in a direction parallel to that of the plastic elongation because of orientation effect of grains. When a component is machined, machining interrupts the continuity of grain flow. In forged parts, the fiber like flow lines of the component are continuous. Forging leads to a re-arrangement of fibers because working is done above recrystallisation temperature.

The original crystals are deformed during forging operation and many of the constituents are precipitated at high temperatures which again become soluble in the solid iron on freezing, thus increasing the local homogeneity of the metal. The properties, like elastic limit, tensile strength of metal are unproved due to the grain flow. If a forged gear blank piece is cut in a plane aligned with the direction and surface is ground smooth and along teeth of the gear blank and immersed in an acid solution, the exposed metal will appear to the naked eye to have a fibre like structure as shown in Fig. 14.5 and Fig.14.6.

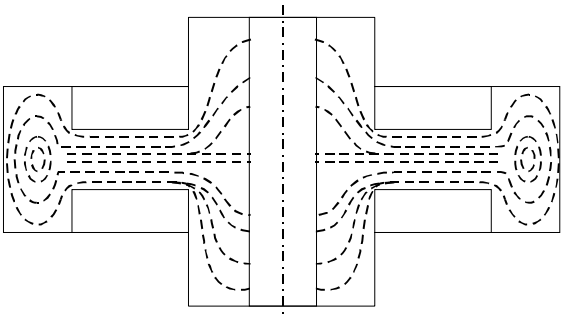


Fig. 14.5 Fibrous forged structure of gear blank

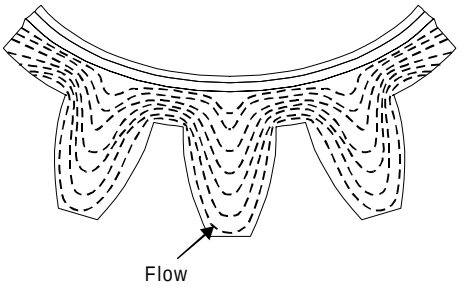


Fig. 14.6

Forging is generally employed for those components which require high strength and resistance to shock or vibrations. It provides fine crystalline structure to the metal, improves physical properties, closes all voids and forms the metal to shapes. It enhances the mechanical properties of metals and improves the grain flow which in turn increases the strength and toughness of the forged component.

But there may be certain defects also, like scale inclusions on the surface, misalignment of the dies, crack, etc. These defects can be controlled. The advantages of forging processes are that, although the metal piece has to be heated to the correct forging temperature before shaping, less metal will be used than if the shape were machined from a solid block of metal. All forgings are covered with scale and hence they require cleaning operation. It is done by

pickling in acid, shot peening or tumbling depending upon the size and composition of the forgings. If some distortion has occurred in forging, a sizing or straightening operation may be required. Controlled cooling is usually provided for large forgings. Heat treatment may also be required to provide certain physical properties. However some common characteristics of forged parts are given as under.

(*i*) Forged parts have directional properties and hence have good strength.

(*ii*) Mechanical properties of materials such as percentage elongation, resistance to stock and vibrations are improved.

(*iii*) Forging process confines the structure of metal by closing up the cavities.

(*iv*) Cracks and blow-holes are minimized in forged parts.

14.9 COMMON HAND FORGING TOOLS

For carrying out forging operations manually, certain common hand forging tools are employed. These are also called blacksmith's tools, for a blacksmith is one who works on the forging of metals in their hot state. The main hand forging tools are as under.

1. Tongs
2. Flatter
3. Swage
4. Fuller
5. Punch
6. Rivet header
7. Hot chisel
8. Hammers
9. Anvil
10. Swage block
11. Drift
12. Set-hammer
14. Brass scale
15. Brass
16. Black smith's gauge
17. Heading tool

Some of the hand forging tool are depicted in Fig.14.7- 14.15 and their applications are described as under.

Tongs

The tongs are generally used for holding work while doing a forging operation. Various kinds of tongs are shown in Fig. 14.7.

1. Flat tongs are used for mainly for holding work of rectangular section.
2. Straight-lip fluted tongs are commonly used for holding square, circular and hexagonal bar stock.
3. Rivet or ring tongs are widely used for holding bolts, rivets and other work of circular section.
4. Gad tongs are used for holding general pick-up work, either straight or tapered.

Flatter

Flatter is shown in Fig. 14.7. It is commonly used in forging shop to give smoothness and accuracy to articles which have already been shaped by fullers and swages.

Swage

Swage (Fig. 14.7) is used for forging work which has to be reduced or finished to round, square or hexagonal form. It is made with half grooves of dimensions to suit the work being

reduced. It consists of two parts, the top part having a handle and the bottom part having a square shank which fits in the hardie hole on the anvil face.

Fuller

Fuller (Fig. 14.7) is used in forging shop for necking down a forgeable job. It is made in top and bottom tools as in the case of swages. Fuller is made in various shapes and sizes according to needs, the size denoting the width of the fuller edge

Punch

Punch (Fig. 14.7) is used in forging shop for making holes in metal part when it is at forging heat.

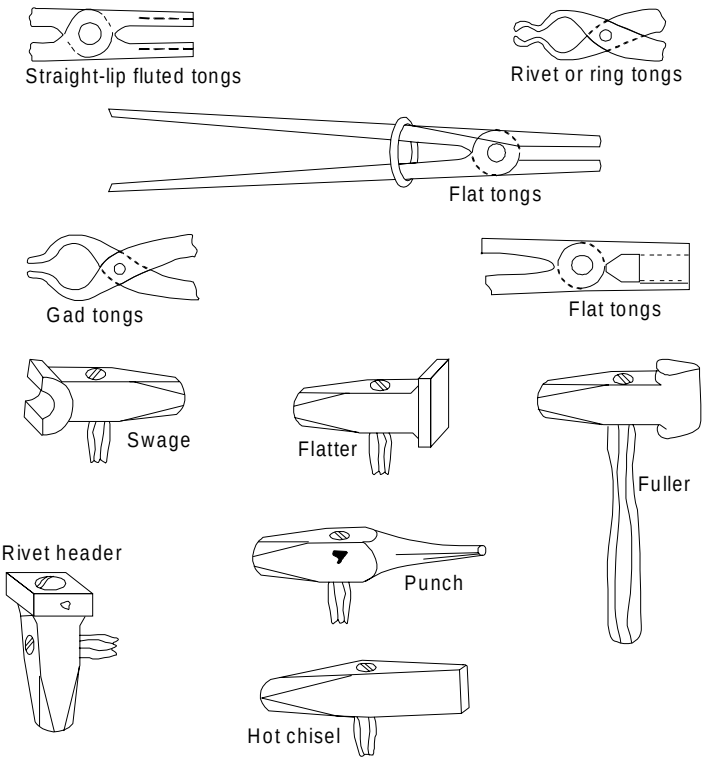


Fig. 14.7 Hand forging tools

Rivet header

Rivet header (Fig. 14.7) is used in forging shop for producing rivets heads on parts.

Chisels

Chisels are used for cutting metals and for nicking prior to breaking. They may be hot or cold depending on whether the metal to be cut is hot or cold. A hot chisel generally used in forging shop is shown in Fig. 14.7. The main difference between the two is in the edge. The edge of a cold chisel is hardened and tempered with an angle of about 60°, whilst the edge of a hot chisel is 30° and the hardening is not necessary. The edge is made slightly rounded for better cutting action.

Hand hammers

There are two major kinds of hammers are used in hand forging: (1) the hand hammer used by the smith himself and (2) the sledge hammer used by the striker. Hand hammers (Fig. 14.8) may further be classified as (*a*) ball peen hammer, (*b*) straight peen hammer, and (*c*) cross peen hammer. Sledge hammers (Fig. 14.8) may further be classified as (*a*) Double face hammer, (*b*) straight peen hammer, and (*c*) cross peen hammer. Hammer heads are made of cast steel and, their ends are hardened and tempered. The striking face is made slightly convex. The weight of a hand hammer varies from about 0.5 to 2 kg where as the weight of a sledge hammer varies from 4 to 10 kg.

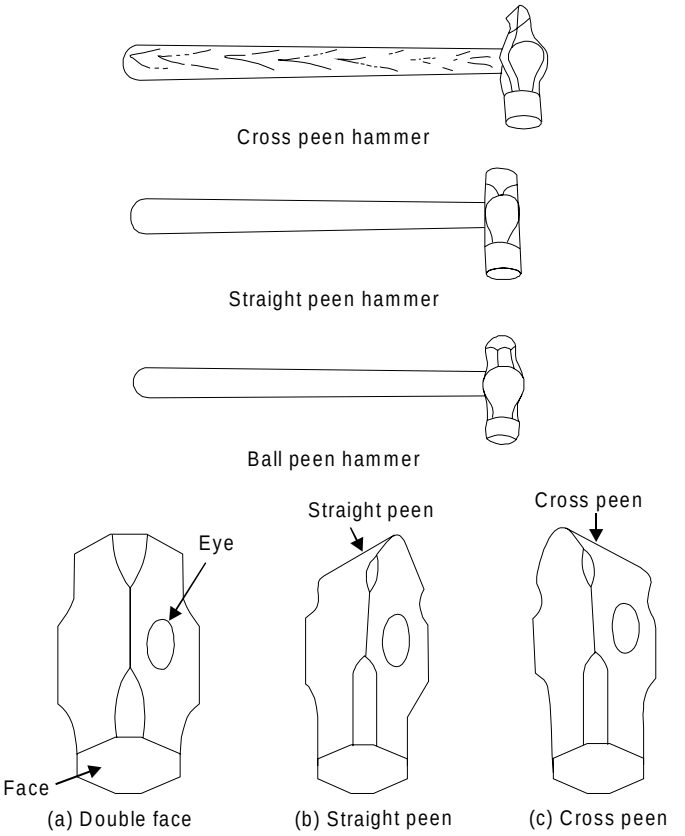


Fig. 14.8 Types of hammers

Set hammer

A set hammer generally used in forging shop is shown in Fig. 14.9. It is used for finishing corners in shouldered work where the flatter would be inconvenient. It is also used for drawing out the gorging job.

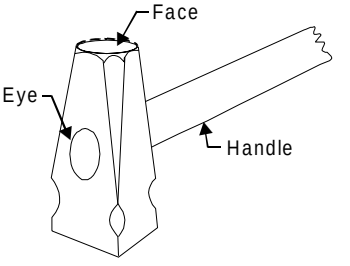


Fig. 14.9 Set hammer

Anvil

An anvil is a most commonly tool used in forging shop which is shown in Fig.14.10. It acts as a support for blacksmith's work during hammering. The body of the anvil is made of mild steel with a tool steel face welded on the body, but the beak or horn used for bending curves is not steel faced. The round hole in the anvil called pritchel hole is generally used for bending rods of small diameter, and as a die for hot punching operations. The square or hardie hole is used for holding square shanks of various fittings. Anvils in forging shop may vary up to about 100 to 150 kg and they should always stand with the top face about 0.75 mt. from the floor. This height may be attained by resting the anvil on a wooden or cast iron base in the forging shop.

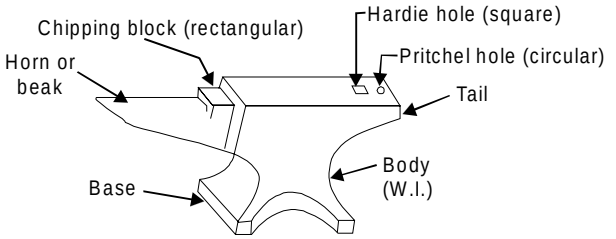


Fig. 14.10 Anvil

Swage block

Swage block generally used in forging shop is shown in Fig. 14.11. It is mainly used for heading, bending, squaring, sizing, and forming operations on forging jobs. It is 0.25 mt. or even more wide. It may be used either flat or edgewise in its stand.

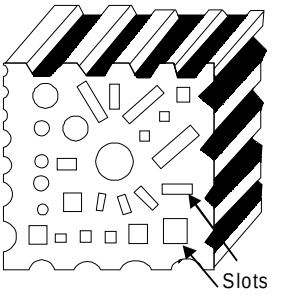


Fig. 14.11 Swage block

Drift

Drift generally used in forging shop is shown in Fig.14.12. It is a tapered rod made of tool steel. Holes are opened out by driving through a larger tapered punch called a drift.

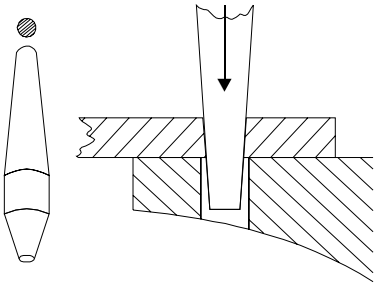


Fig. 14.12 Drift

Hardie

Hardie is a type of chisel used in forging shop. It is shown in Fig. 14.13. Its taper head is fixed into the hardie hole of the anvil, the cutting edge being upward. The part to be cut is kept over the cutting edge of the fixed hardie on anvil and another chisel is placed over the job and the cutting is performed by hammering.

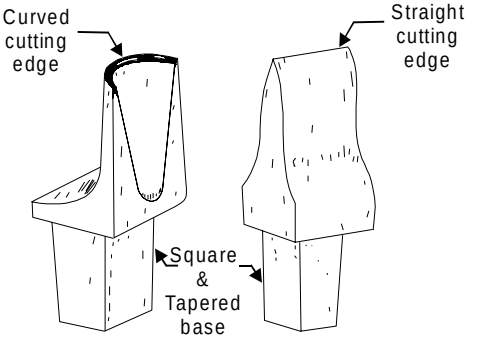


Fig. 14.13 Hardie

Shovel

Shovel generally used in forging shop is shown in Fig. 14.14. It is used to place coal or coke in the furnace. It is also used to set coal pieces in furnace and remove ash from furnace.

Poker

Poker (Fig.14.14) is employed for removing clinker from the furnace and to loose the compact coal pieces in the furnace.

Rake

Rake (Fig. 14.14) is used to put coal pieces on tuyres.

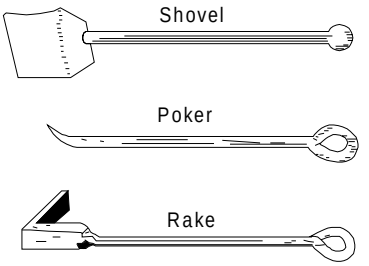


Fig. 14.14 Shovel, Poker and Rake

Beak Iron

Beak iron generally used in forging shop is shown in Fig. 14.15. It is also known as small anvil made of forged steel. Its upper front end consists of horn and upper back end comprises of flat tail. Its taper shank is inserted into the hardie hole of the anvil. It is commonly used as anvil for small forge work.

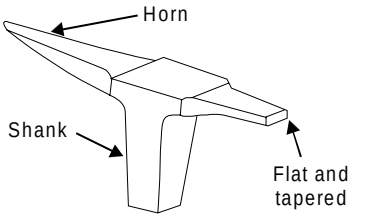


Fig. 14.15 Beak iron

14.10 FORGING METHODS

The forging methods are commonly used for changing the shape of the raw material in to the finished form in the forging shop are generally classified into two categories namely hand forging and power forging. These are being discussed as under

14.10.1 Hand forging

Hand forging is performed in the black smithy shop. The job is heated at the forging temperature in hearth and it is then brought on anvil using tong. It is then forged using hand hammers and other hand forging tools for imparting specific shape.

14.10.1.1 Forging Operations

The hand forging operations (Fig. 14.16) are

1. Upsetting
2. Bending
3. Drawing down
4. Cutting
5. Setting down
6. Punching
7. Flattening
8. Fullering
9. Forge Welding
10. Swaging

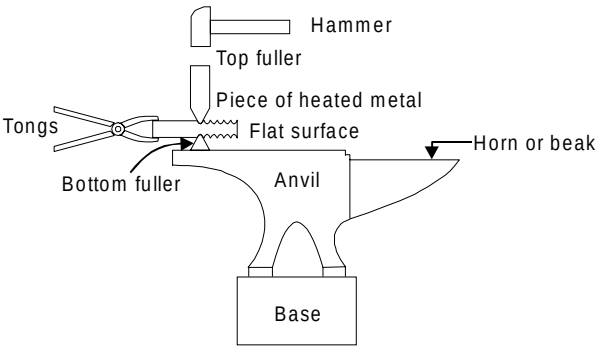


Fig. 14.16 Hand forging

Some important hand forging operations are described as under.

(*i*) Drawing out

Drawing out is used to reduce the thickness of a bar and to increase its length. It may be carried out by working the metal over the horn the anvil as shown in Fig. 14.17, then by hammering it on the anvil face. The rounded horn of the anvil acts as a blunt edge, which forces the metal to flow lengthwise when struck by the hammer. For drawing down very heavy work, fuller may be used for drawing down a bar over the horn (round portion) of anvil.

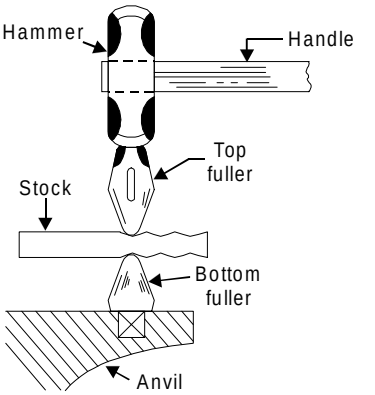


Fig. 14.17 Drawing out

(*ii*) Fullering

Fullering operation generally used in forging shop is shown in Fig. 14.18. It involves heating the stock in the black smith hearth. Then heated stock is placed on the fuller fixed on anvil. A fuller is put over the sock and hammering is done to reduce the cross section of job at required point.

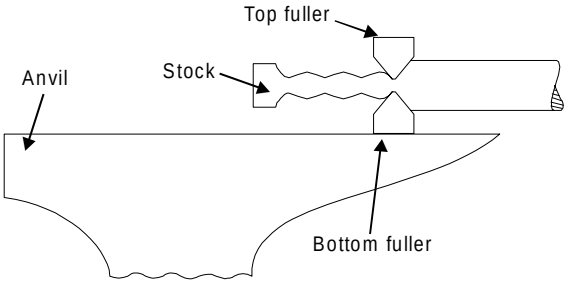


Fig. 14.18 Fullering

(*iii*) Upsetting

Upsetting is also known as jumping operation which is carried out to increase the thickness (or diameter) of a bar and to reduce its length. Generally, the increase in thickness is only local, for example, when forming a bolt head. This operation is an operation just

opposite to drawing and involves increasing the cross-sectional area usually by hammering or pressing in a direction parallel to the ingot axis. The length of the ingot decreases and following the path of least resistance it spreads out. The required shape is given the ingot by spreading it between two dies. Only that portion of the bar which is to be upset is heated locally. Or, the whole bar is heated and except for the portion to be upset, the rest is quenched in water so that upset will form only on the hot portion of the bar. In one method of upsetting, the bar is held in the tong and supported vertically on the anvil. The top edge of the bar is then hammered to form the upset on the bottom hot end of the bar. For upsetting, the blow of the hammer must be in line with the bar to prevent bending of the bar.

(iv) Bending

Bending is a very commonly used forging operation in forging shop to give a turn to a metal rod or plate. It is accompanied by spreading of the metal in the inside of the bend and narrowing at outside. The simplest method of bending a piece of metal in hand forging is to support it on the anvil and to strike its free end with a hammer When bent, the metal of the workpiece thins out round bend causing weakness. This can be overcome by upsetting the bar prior to bending.

(*v*) Cutting

Cutting is a main forging operation to cut out a metal rod or plate into two pieces with the help of a chisel and hammer when the metal is in red hot condition. A hot or cold cut (chisel) is used for cutting heated metal bars in a smithy shop. The hot set does not require hardening and tempering. Its cutting edge is keener than that of a cold set. Hot sets are manufactured from a tough variety of steel in order that they may cut through relatively soft red-hot metal with ease. While cutting, it is best to cut half through the workpiece to turn it over and cut through from the other end.

(*vi*) Punching

Punching is a main forging operation used for producing hole in metal plate by using a tool known as punch. The metal plate is placed over the hollow cylindrical die and punch is placed above it at required location where hole is being made. For punching a hole, the metal job must be at near welding heat and the punch is driven part way through the job with hammer blows. The work is then turned over and the hole is completed from the other side. The above said practice is adopted for thicker jobs.

(*vii*) Forge Welding

It is a process of joining two metal pieces to increase the length by pressing or hammering them when they are at forging temperature. It is performed in forging shop and hence sometimes it is called as forge welding.

14.10.2 Power Forging

Hand hammer blows impact will not be always sufficient enough to affect the proper plastic flow in a medium sized or heavy forging. It also causes fatigue to the hammer man. To have heavy impact or blow for more plastic deformation, power hammer are generally employed. These hammers are operated by compressed air, steam, oil pressure, spring and gravity. They are generally classified as spring hammer and drop hammers. The capacity of these hammers is given by the total weight. A 100 kg hammer will be one of which the falling pans weigh 100 kg. The heavier these parts and greater the height from which they fall, the higher will be

intensity of blow the hammer will provide. Power hammers are of different types e.g. spring power hammers, pneumatic power hammers etc. These hammers are named due to their construction, according to their way of operation and according to the type of fuel they use for getting the required power for operation. Besides these, a large number of forging presses are also used in forging work. Typical hammers are discussed in following in following paragraphs.

14.10.2.1 Spring Hammer

Spring hammer is commonly used for small forgings. It is light type of power hammer. The typical design of a spring hammer is shown in Fig. 14.19. It consists of a heavy rigid frame carrying a vertical projection at its top. This projection acts as a housing of bearing in which the laminated spring oscillates. The rear end of this spring carries a connecting rod and the other front end a vertical top which carries weight and moves vertically up and down between fixed guides provided for this purpose. The connecting rod at its lower end is attached to an eccentric sheave, which is further connected to the crank wheel. Fox operating the hammer the treadle is pressed downwards which makes the sheave to rotate through the crank wheel and thus the laminated spring starts oscillating in the bearing. This oscillation of the spring is responsible for the up and down movement of the tup thus, the required blows are provided on the job to be forged. A hand lever is also equipped with this mechanical kind of hammer to adjust the stroke of the connecting rod and, hence the intensity of blows. Eccentric type of spring hammer is the one in which a rotating eccentric disc is used for producing vibrations in the spring. It can be operated by means of a foot ring, known as treadle provided at the bottom and is connected to the shaft at the top through a vertical bar having a clutch at its end. The shaft at the top of hammer carries a pulley and a solid disc at the end. The pulley is driven by means of a belt from the line shaft or an electric motor. The solid disc, at the, end of the shaft, carries a crank connected eccentrically to it which has a laminated spring at its lower end. The nip carrying the weight is suspended on a toggle joint connecting the two ends of the laminated spring. When the foot treadle is pressed the clutch engages with the shaft and the disc carrying the crank starts rotating which in turn produces fluctuations in the toggle joint of the machine. It makes the tup to move and down in vertical direction. The speed of blows entirely depends upon the speed of the driving pulley.

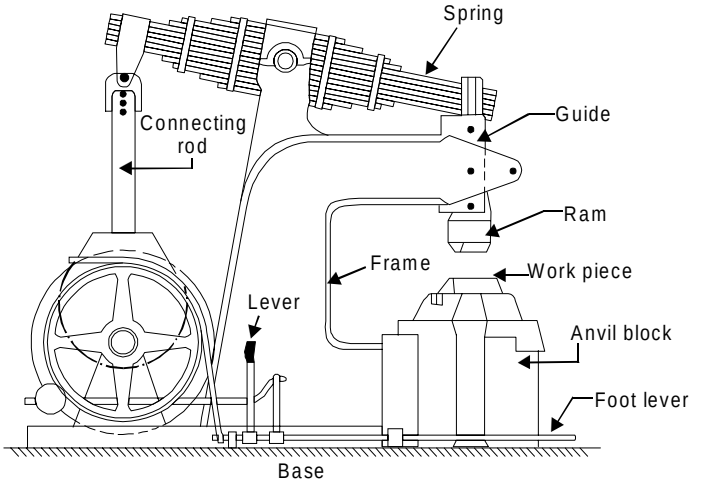


Fig. 14.19 Spring hammer

Spring hammers may be made available in various capacities having the tup weights from 30 to 250 kg. Those having top weights 50 to 100 kg and speed of blows up to 300 per minute are in generally used in forging shop. These hammers have a common drawback in their springs getting broken very frequently due to severe vibrations during forging of the jobs in the forging shop.

14.10.2.2 Drop Hammers

Drop hammers are operated hydraulically and are widely used for shaping parts by drop hammering a heated bar or billet into a die cavity as shown in Fig. 14.20. A drop forging raises a massive weight and allows it to fall under gravity on close dies in which forge component is allowed to be compressed. The die incorporates its shape on to the hot work piece as shown in Fig. 14.21. Drop hammers are commonly used for forging copper alloys and steel.

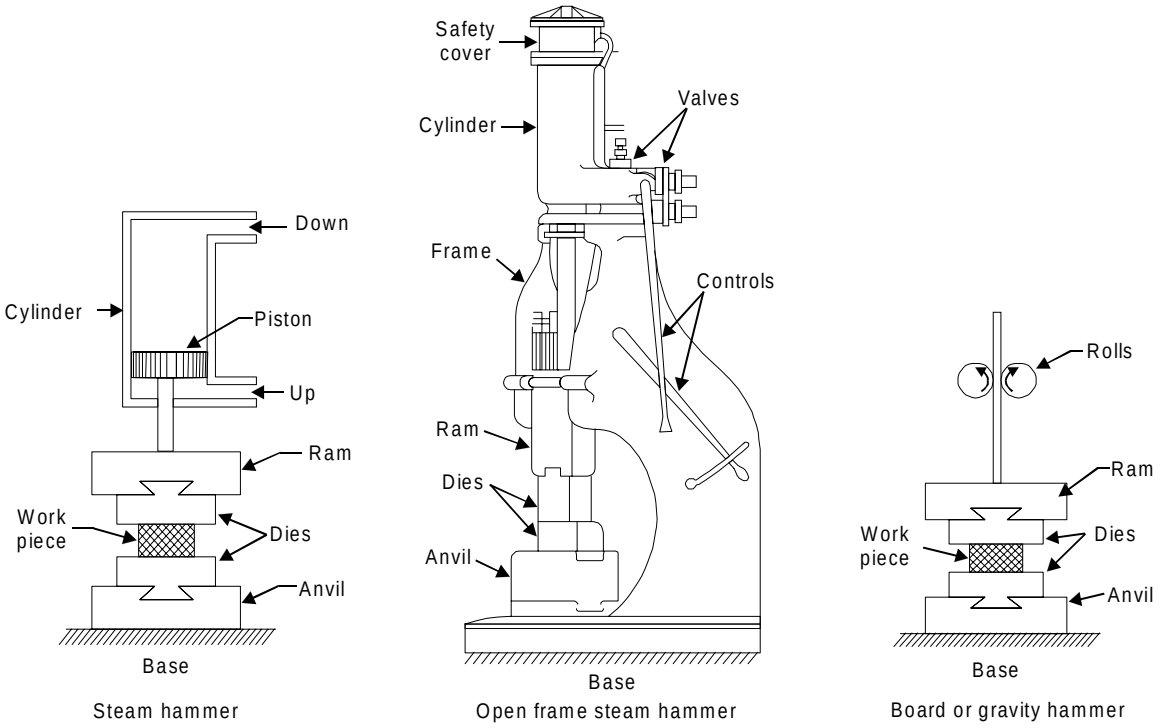


Fig. 14.20 Drop hammers

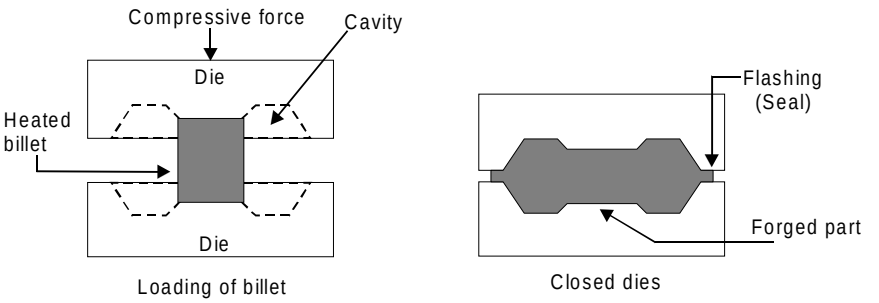


Fig. 14.21 Close die forging

14.10.2.3 Design Principles for drop forging

Certain principles for drop forgings generally followed are given as under:

1. The sections of the forging should be balanced about the parting line. Where this is impossible, design for the simplest irregular parting line which approaches a balanced condition.
2. Generous inside fillets and external radio should be allowed. Minimum radius should be 2 mm for small parts and 4 mm for large parts.
3. Sufficient draft should be allowed for easy removal of: the part, as follows:

14.11 DEFECTS IN FORGED PARTS

Defects commonly found in forged parts that have been subjected to plastic deformation are as follows.

(*i*) Defects resulting from the melting practice such as dirt, slag and blow holes.

(*ii*) Ingot defects such as pikes, cracks scabs, poor surface and segregation.

(*iii*) Defect due to faulty forging design.

(*iv*) Defects of mismatched forging because of improper placement of the metal in the die.

(*v*) Defects due to faulty design drop forging die.

(*vi*) Defects resulting from improper forging such as seams cracks laps. etc.

(*vii*) Defects resulting from improper heating and cooling of the forging part such as burnt metal and decarburized steel.

Some well identified common forging defects along with their reason are given as under.

1. Mismatched forging

Reasons

Due to non alignment of proper die halves.

2. Brunt and overheated metal

Reasons

This is caused by improper heating the metal at high temperature or for a long time.

3. Fibred flow lines discontinued

Reasons

This will occur because of very rapid plastic flow of metal.

4. Scale pits

Reason

These are formed by squeezing of scale into the metal surface during forging.

5. Oversize components

Reasons

Due to worn out dies, incorrect dies, misalignment of die halves.

14.12 REMOVAL OF DEFECTS IN FORGING

Defects in forging can be removed as follows:

(*i*) Surface cracks and decarburized areas are removed from forging parts by grinding on special machines. Care should also be taken to see that the job is not under heated, decarburized, overheated and burnt.

(*ii*) Shallow cracks and cavities can be removed by chipping out of the cold forging with pneumatic chisel or with hot sets.

(*iii*) The parting line of a forging should lie in one plane to avoid mismatching.

(*iv*) Destroyed forgings are straightened in presses, if possible.

(*v*) Die design should be properly made taking into consideration all relevant and important aspects that may impart forging defects and ultimate spoilage

(*vi*) The mechanical properties of the metal can be improved by forging to correct fibre line. The internal stresses developed due to heating and cooling of the job can be removed by annealing or normalizing.

14.13 GENERAL CONSIDERATIONS ADOPTED FOR DESIGNING A FORGING JOB

There are some common considerations adopted while designing a forging job and the same are given below.

1. Sufficient draft on surfaces should be provided to facilitate easy removal of forgings from the dies. It depends mainly on the depth of the die cavity. The greater the depth, the larger draft will be the required. Generally, however, a 1 to 5 degrees draft is provided on press forgings and 3 to 10 degrees on drop forgings.
2. Sharp corners where ever occur should always be avoided as far as possible to prevent concentration of stresses leading to fatigue failures and to facilitate ease in forging. The usual practice is to provide fillets of more than 1.6 mm radius. The exact size of the fillet is however decided according the size of the forging. If a perfectly sharp corner is required, the fillet can be removed at later stage.
3. Forgings which are likely to carry flash, such as in drop and press forgings, should preferably have the parting line in such a position that the same will divide them in two equal halves.
4. As far as possible the parting line of a forging should lie in one plane.
5. The forged component should ultimately be able to achieve a radial flow of grains or fibres.
6. Attention should be given to avoid the presence of pockets and recesses in forgings. If they cannot be avoided, their number should be reduced to a minimum as far as possible.
7. High and thin ribs should not be designed. Also, cavities which are deeper than their diameters should be avoided.
8. Metal shrinkage and forging method should be duly taken into account while deciding the forging and finishing temperatures.
9. Although it is possible to achieve quite close tolerances of the order of 0.4 mm on either side through forging and therefore it is adequate to provide allowances to

compensate for metal shrinkage, machining, die wear, trimming and mis-match of dies.

10. Too thin sections in parts should be avoided to facilitate an easy flow of metal.

14.14 HEAT TREATMENT OF FORGING

Heat treatment is carried out for releasing the internal stresses arising in the metal during forging and cooling of work piece. It is used for equalizing the granular structure of the forged metal and improving the various mechanical properties. Generally forged parts are annealed, normalized and tempered to obtain the desired results.

14.15 SAFETY PRECAUTIONS

Some safety precautions generally followed while working in forging shop are given as under.

1. Always avoid the use of damaged hammers.
2. Never strike a hardened surface with a hardened tool.
3. No person should be allowed to stand in line with the flying objects.
4. Always use the proper tongs according to the type of work.
5. The anvil should always be free from moisture and grease while in use.
6. Always wear proper clothes, foot-wears and goggles.
7. The handle of the hammer should always be tightly fitted in the head of the hammer.
8. Always put out the fire in the forge before leaving the forge shop.
9. Always keep the working space clean.
10. Proper safety guards should be provided on all revolving parts.
11. Head of the chisel should be free from burrs and should never be allowed to spread.
12. During machine forging, always observe the safety rules prescribed for each machine.
13. One must have the thorough knowledge of the working of the forging machine before operating it.

14.16 QUESTIONS

1. What is the difference between smithy and forging?
2. What do you understand by open fire and stock fire? Which of the two is more advantageous and why?
3. Explain the various types of furnaces used in forging work?
4. Write Short notes on:
    1. Drop forging
    2. Press forging
    3. Flattening
    4. Smith's Forge
    5. Pedestal grinder
    6. Power hammers

7. Pneumatic riveting machine
8. Layout of smithy or forging shop.

5 Sketch and describe the following forging tools

(*i*) Anvil. (*ii*) Swage Block, (*iii*) Set hammers
(*iv*) Punches, (*v*) Drift, and (*vi*) Hardie

6 Explain with neat sketches the following forging operations:

(*i*) Upsetting, (*ii*) Drawing down, (*iii*) Bending,
(*iv*) Drifting, (*v*) Punching, (*vi*) Welding
(*vii*) Fullering

7 Describe press forging. How does it differ from drop forging?

8 Describe in brief the various types of forgings?

9 Explain in brief the defects in forging?

10 Why heat treatment is necessary for forging?

11 What are the main considerations in designing a forging?

12 Explain in brief the various safety precautions associated with the forging shop?

15
CHAPTER

HOT WORKING OF METALS

15.1 METAL FORMING

Metal forming is also known as mechanical working of metals. Metal forming operations are frequently desirable either to produce a new shape or to improve the properties of the metal. Shaping in the solid state may be divided into non-cutting shaping such as forging, rolling, pressing, etc., and cutting shaping such as the machining operations performed on various machine tools. Non-cutting or non machining shaping processes are referred to as mechanical working processes. It means an intentional and permanent deformation of metals plastically beyond the elastic range of the material. The main objectives of metal working processes are to provide the desired shape and size, under the action of externally applied forces in metals. Such processes are used to achieve optimum mechanical properties in the metal and reduce any internal voids or cavities present and thus make the metal dense.

Metals are commonly worked by plastic deformation because of the beneficial effect that is imparted to the mechanical properties by it. The necessary deformation in a metal can be achieved by application of mechanical force only or by heating the metal and then applying a small force. The impurities present in the metal are thus get elongated with the grains and in the process get broken and dispersed through out the metal. This also decreases the harmful effect of the impurities and improves the mechanical strength. This plastic deformation of a metal takes place when the stress caused in the metal, due to the applied forces reaches the yield point. The two common phenomena governing this plastic deformation of a metal are (*a*) deformation by slip and (*b*) deformation by twin formation. In the former case it is considered that each grain of a metal is made of a number of unit cells arranged in a number of planes, and the slip or deformation of metal takes place along that slip plane which is subjected to the greatest shearing stress on account of the applied forces. In the latter case, deformation occurs along two parallel planes, which move diagonally across the unit cells. These parallel planes are called twinning planes and the portion of the grains covered between them is known as twinned region. On the macroscopic scale, when plastic deformation occurs, the metal appears to flow in the solid state along specific directions, which are dependent on the processing and the direction of applied forces. The crystals or grains of the metal get elongated in the direction of metal flow. However this flow of metal can be easily be seen under microscope after polishing and suitable etching of the metal surface. The visible lines are called fibre flow lines. The above deformations may be carried out at room temperature or higher temperatures. At higher temperatures the deformation is faster because the bond

between atoms of the metal grains is reduced. Plasticity, ductility and malleability are the properties of a material, which retains the deformation produced under applied forces permanently and hence these metal properties are important for metal working processes.

Plasticity is the ability of material to undergo some degree of permanent deformation without rupture or failure. Plastic deformation will take place only after the elastic range has been exceeded. Such property of material is important in forming, shaping, extruding and many other hot and cold working processes. Materials such as clay, lead, etc. are plastic at room temperature and steel is plastic at forging temperature. This property generally increases with increase in temperature.

Ductility is the property of a material enabling it to be drawn into wire with the application of tensile force. A ductile material must be both strong and plastic. The ductility is usually measured by the terms percentage elongation and percent reduction in area often used as empirical measures of ductility. The ductile material commonly used in engineering practice in order of diminishing ductility are mild steel, copper, aluminium, nickel, zinc, tin and lead.

Malleability is the ability of the material to be flattened into thin sheets without cracking by hot or cold working. A malleable material should be plastic but it is not essential to be so strong. The malleable materials commonly used in engineering practice in order of diminishing malleability are lead, soft steel, wrought iron, copper and aluminium. Aluminium, copper, tin, lead, steel, etc. are recognized as highly malleable metals.

15.2 RECRYSTALISATION

During the process of plastic deformation in metal forming, the plastic flow of the metal takes place and the shapes of the grains are changed. If the plastic deformation is carried out at higher temperatures, new grains start growing at the location of internal stresses caused in the metal. If the temperature is sufficiently high, the growth of new grains is accelerated and continuous till the metal comprises fully of only the new grains. This process of formation of new grains is known as recrystallisation and is said to be complete when the metal structure consists of entirely new grains. That temperature at which recrystalisation is completed is known as the recrystallisation temperature of the metal. It is this point, which draws the line of difference between cold working and hot working processes. Mechanical working of a metal below its recrystalisation temperature is called as cold working and that accomplished above this temperature but below the melting or burning point is known as hot working.

15.3 HOT WORKING

Mechanical working processes which are done above recrystallisation temperature of the metal are know as hot working processes. Some metals, such as lead and tin, have a low recrystallisation temperature and can be hot-worked even at room temperature, but most commercial metals require some heating. However, this temperature should not be too high to reach the solidus temperature; otherwise the metal will burn and become unsuitable for use. In hot working, the temperature of completion of metal working is important since any extra heat left after working aid in grain growth. This increase in size of the grains occurs by a process of coalescence of adjoining grains and is a function of time and temperature. Grain growth results in poor mechanical properties. If the hot working is completed just above the recrystallisation temperature then the resultant grain size would be fine. Thus for

any hot working process the metal should be heated to such a temperature below its solidus temperature, that after completion of the hot working its temperature will remain a little higher than and as close as possible to its rccrystalisation temperature

15.4 EFFECT OF HOT WORKING ON MECHANICAL PROPERTIES OF METALS

1. This process is generally performed on a metal held at such a temperature that the metal does not work-harden. A few metals e.g., Pb and Sn (since they possess low crystallization temperature) can be hot worked at room temperature.
2. Raising the metal temperature lowers the stresses required to produce deformations and increases the possible amount of deformation before excessive work hardening takes place.
3. Hot working is preferred where large deformations have to be performed that do not have the primary purpose of causing work hardening.
4. Hot working produces the same net results on a metal as cold working and annealing. It does not strain harden the metal.
5. In hot working processes, compositional irregularities are ironed out and non-metallic impurities are broken up into small, relatively harmless fragments, which are uniformly dispersed throughout the metal instead of being concentrated in large stress-raising metal working masses.
6. Hot working such as rolling process refines grain structure. The coarse columnar dendrites of cast metal are refined to smaller equiaxed grains with corresponding improvement in mechanical properties of the component.
7. Surface finish of hot worked metal is not nearly as good as with cold working, because of oxidation and scaling.
8. One has to be very careful as regards the temperatures at which to start hot work and at which to stop because this affects the properties to be introduced in the hot worked metal.
9. Too high a temperature may cause phase change and overheat the steel whereas too low temperature may result in excessive work hardening.
10. Defects in the metal such as blowholes, internal porosity and cracks get removed or welded up during hot working.
11. During hot working, self-annealing occurs and recrystallization takes place immediately following plastic deformation. This self-annealing action prevents hardening and loss of ductility.

15.5 MERITS OF HOT WORKING

1. As the material is above the recrystallisation temperature, any amount of working can be imparted since there is no strain hardening taking place.
2. At a high temperature, the material would have higher amount of ductility and therefore there is no limit on the amount of hot working that can be done on a material. Even brittle materials can be hot worked.
3. In hot working process, the grain structure of the metal is refined and thus mechanical properties improved.

4. Porosity of the metal is considerably minimized.
5. If process is properly carried out, hot work does not affect tensile strength, hardness, corrosion resistance, etc.
6. Since the shear stress gets reduced at higher temperatures, this process requires much less force to achieve the necessary deformation.
7. It is possible to continuously reform the grains in metal working and if the temperature and rate of working are properly controlled, a very favorable grain size could be achieved giving rise to better mechanical properties.
8. Larger deformation can be accomplished more rapidly as the metal is in plastic state.
9. No residual stresses are introduced in the metal due to hot working.
10. Concentrated impurities, if any in the metal are disintegrated and distributed throughout the metal.
11. Mechanical properties, especially elongation, reduction of area and izod values are improved, but fibre and directional properties are produced.
12. Hot work promotes uniformity of material by facilitating diffusion of alloy constituents and breaks up brittle films of hard constituents or impurity namely cementite in steel.

15.6 DEMERITS OF HOT WORKING

1. Due to high temperature in hot working, rapid oxidation or scale formation and surface de-carburization take place on the metal surface leading to poor surface finish and loss of metal.
2. On account of the loss of carbon from the surface of the steel piece being worked the surface layer loses its strength. This is a major disadvantage when the part is put to service.
3. The weakening of the surface layer may give rise to a fatigue crack which may ultimately result in fatigue failure of the component.
4. Some metals cannot be hot worked because of their brittleness at high temperatures.
5. Because of the thermal expansion of metals, the dimensional accuracy in hot working is difficult to achieve.
6. The process involves excessive expenditure on account of high cost of tooling. This however is compensated by the high production rate and better quality of components.
7. Handling and maintaining of hot working setups is difficult and troublesome.

15.7 CLASSIFICATION OF HOT WORKING PROCESSES

The classification of hot working processes is given as under.

1. Hot rolling
2. Hot forging
3. Hot extrusion
4. Hot drawing

5. Hot spinning
6. Hot piercing or seamless tubing
7. Tube Forming and
8. Hot forming of welded pipes

Some of the important hot working processes are described as under.

15.8 PRINCIPAL HOT WORKING PROCESSES

15.8.1 Hot Rolling

Rolling is the most rapid method of forming metal into desired shapes by plastic deformation through compressive stresses using two or more than two rolls. It is one of the most widely used of all the metal working processes. The main objective of rolling is to convert larger sections such as ingots into smaller sections which can be used either directly in as rolled state or as stock for working through other processes. The coarse structure of cast ingot is convened into a fine grained structure using rolling process as shown in Fig. 15.1. Significant improvement is accomplished in rolled parts in their various mechanical properties such as toughness, ductility, strength and shock resistance. The majority of steel products are being converted from the ingot form by the process of rolling. To the steel supplied in the ingot form the preliminary treatment imparted is the reduction in its section by rolling as shown in figure. The crystals in parts are elongated in the direction of rolling, and they start to reform after leaving the zone of stress. Hot rolling process is being widely used in the production of large number of useful products such as rails, sheets, structural sections, plates etc. There are different types of rolling mills, which are described as under.

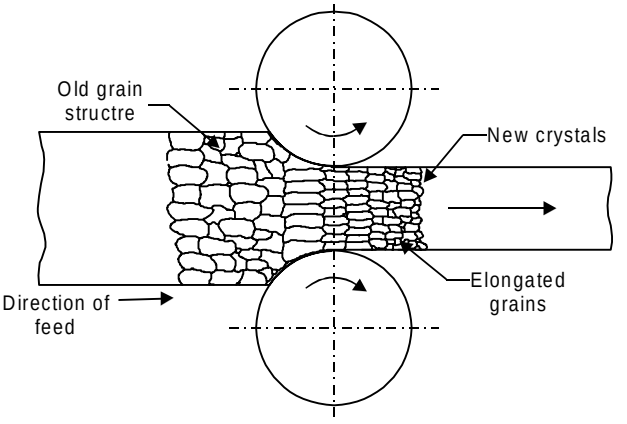


Fig. 15.1 Grain refinement in hot rolling process

15.8.1 Two-High Rolling Mill

A two-high rolling mill (Fig 15.2(a)) has two horizontal rolls revolving at the same speed but in opposite direction. The rolls are supported on bearings housed in sturdy upright side frames called stands. The space between the rolls can be adjusted by raising or 1owering the upper roll. Their direction of rotation is fixed and cannot be reversed. The reduction in the thickness of work is achieved by feeding from one direction only. However, there is another

type of two-high rolling mill, which incorporates a drive mechanism that can reverse the direction of rotation of the rolls. A Two- high reverse arrangement is shown in Fig. 15.2(b). In a two-high reversing rolling mill, there is continuous rolling of the workpiece through back-and-forth passes between the rolls.

15.8.2 Three-High Rolling Mills

It consists of three parallel rolls, arranged one above the other as shown in Fig. 15.2(c). The directions of rotation of the upper and lower rolls are the same but the intermediate roll rotates in a direction opposite to both of these. This type of rolling mill is used for rolling of two continuous passes in a rolling sequence without reversing the drives. This results in a higher rate of production than the two-high rolling mill.

15.8.3 Four-High Rolling Mill

It is essentially a two-high rolling mill, but with small sized rolls. Practically, it consists of four horizontal rolls, the two middle rolls are smaller in size than the top and bottom rolls as shown in Fig. 15.2(d). The smaller size rolls are known as working rolls which concentrate the total rolling pressure over the workpiece. The larger diameter rolls are called back-up rolls and their main function is to prevent the deflection of the smaller rolls, which otherwise would result in thickening of rolled plates or sheets at the centre. The common products of these mills are hot or cold rolled plates and sheets.

15.8.4 Cluster Mill

It is a special type of four-high rolling mill in which each of the two smaller working rolls are backed up by two or more of the larger back-up rolls as shown in Fig. 15.2(e). For rolling hard thin materials, it may be necessary to employ work rolls of very small diameter but of considerable length. In such cases adequate support of the working rolls can be obtained by using a cluster-mill. This type of mill is generally used for cold rolling work.

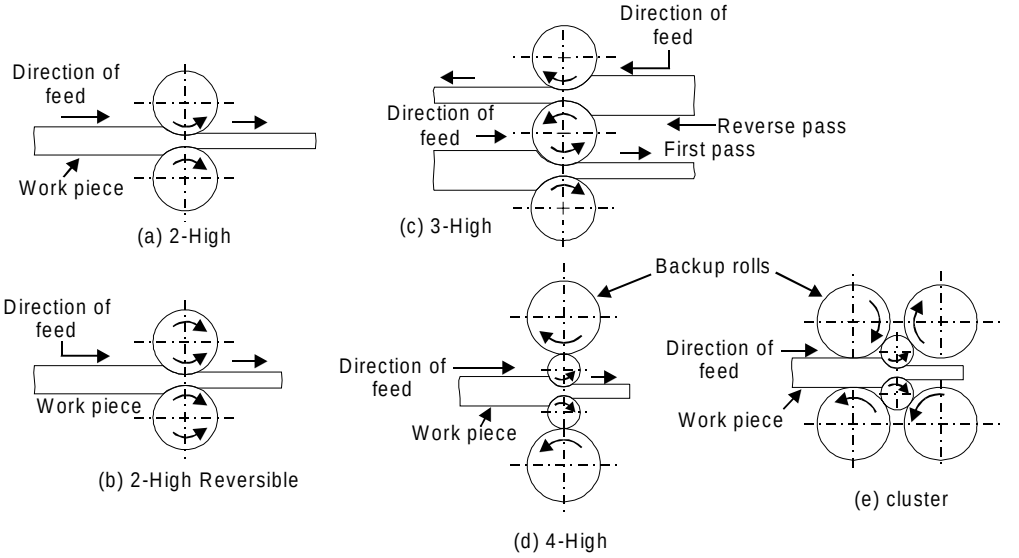


Fig. 15.2 Hot rolling stand arrangements

15.8.5 Continuous Rolling Mill

It consists of a number of non reversing two-high rolling mills arranged one after the other, so that the material can be passed through all of them in sequence. It is suitable for mass production work only, because for smaller quantities quick changes of set-up will be required and they will consume lot of time and labor.

15.8.6 Applications of Rolling

In the rail mill (Fig. 15.2(f)), the heavier structural sections and rails are made. Rolling mills produce girders, channels, angle irons and tee-irons. Plate mill rolls slabs into plates. The materials commonly hot rolled are aluminium, copper magnesium, their alloys and many grades of steel.

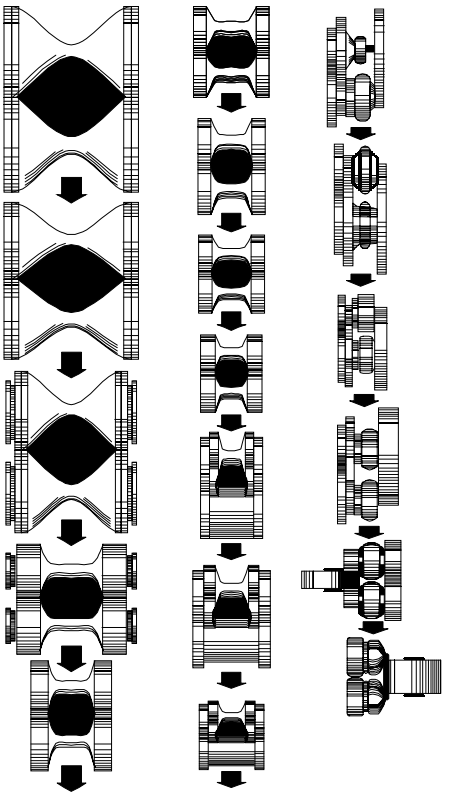


Fig. 15.2(f) Hot rolling stand arrangements

15.9 Hot Piercing or Seamless tubing

Hot piercing is also known as seamless tubing or roll piercing process. The process setup is shown in Fig. 15.3. It is used for making thin-walled round objects. Seamless tube forming is popular and economical process in comparison to machining because it saves material wasted in boring of parts.

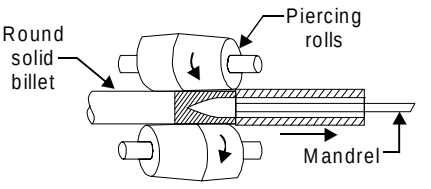


Fig. 15.3 Hot piercing or seamless tubing

Hot pircing includes rotary piercing to obtain formed tube by piercing a pointed mandrel through a billet in a specially designed rolling mill. The rotary piercing can be performed either on a two-high rolling mill or on a three-high rolling mill. In the former, the two rolls are set at an angle to each other. The billet under the rolls is deformed and a cavity formation is initiated at the centre due to tensile stressing. The carefully profiled shape of the mandrel assists and controls the formation of cavity. In a three-high rolling mill, the three shaped rolls are located at 1200 and their axes are inclined at a feed angle to permit forward and rotary motion of the billet. The squeezing and bulging of the billet open up a seam in its center pass makes a rather thick-walled tube which is again passed over plug and through grooved rolls in a two-high roll mill where the thickness is decreased and the length is increased. While it is still up to a temperature, it is passed on to a reeling machine which has two rolls similar to the piercing rolls, but with flat surfaces. If more accuracy and better finish are desired, the run through sizing dies or rolls. After cooling, the tubes are used in a pickling bath of dilute sulphuric acid to remove the scale.

15.10 HOT EXTRUSION

It is the process of enclosing the heated billet or slug of metal in a closed cavity and then pushing it to flow from only one die opening so that the metal will take the shape of the opening. The pressure is applied either hydraulically or mechanically. Extrusion process is identical to the squeezing of tooth paste out of the tooth paste tube. Tubes, rods, hose, casing, brass cartridge, moulding-trims, structural shapes, aircraft parts, gear profiles, cable sheathing etc. are some typical products of extrusion. Using extrusion process, it is possible to make components, which have a constant cross-section over any length as can be had by the rolling process. The intricacy in parts that can be obtained by extrusion is more than that of rolling, because the die required being very simple and easier to make. Also extrusion is a single pass process unlike rolling. The amount of reduction that is possible in extrusion is large. Generally brittle materials can also be easily extruded. It is possible to produce sharp corners and re-entrant angles. It is also possible to get shapes with internal cavities in extrusion by the use of spider dies, which are explained later.

The extrusion setup consists of a cylinder container into which the heated billet or slug of metal is loaded. On one end of the container, the die plate with the necessary opening is fixed. From the other end, a plunger or ram compresses the metal billet against the container walls and the die plate, thus forcing it to flow through the die opening, acquiring the shape of the opening. The extruded metal is then carried by the metal handling system as it comes out of the die.

The extrusion ratio is defined as the ratio of cross- sectional area of the billet to that of the extruded section. The typical values of the extrusion ratio are 20 to 50. Horizontal hydraulic presses of capacities between 250 to 5500 tonnes are generally used for conventional extrusion. The pressure requirement for extrusion is varying from material to material. The extrusion pressure for a given material depends on the extrusion temperature, the reduction in area and the extrusion speed.

15.10.1 Methods of Hot Extrusion

Hot extrusion process is classified as

1. Direct or forward hot extrusion
2. Indirect or backward hot extrusion
3. Tube extrusion

Different methods of extrusion are shown in Fig. 15.4. Each method is described as under.

15.10.1.1 Direct or Forward Hot Extrusion

Fig. 15.4 (a) shows the direct extrusion operational setup. In this method, the heated metal billet is placed in to the die chamber and the pressure is applied through ram. The metal is extruded through die opening in the forward direction, i.e. the same as that of the ram. In forward extrusion, the problem of friction is prevalent because of the relative motion between the heated metal billet and the cylinder walls. To reduce such friction, lubricants are to be commonly used. At lower temperatures, a mixture of oil and graphite is generally used. The problem of lubrication gets compounded at the higher operating temperatures. Molten glass is generally used for extruding steels.

15.10.1.2 Indirect or Backward Hot Extrusion

Fig. 15.4 (b) shows the indirect extrusion operational setup. In indirect extrusion, the billet remains stationary while the die moves into the billet by the hollow ram (or punch), through which the backward extrusion takes place. Since, there is no friction force between the billet and the container wall, therefore, less force is required by this method. However this process is not widely used because of the difficulty occurred in providing support for the extruded part.

15.10.1.3 Tube Extrusion

Fig. 15.4 (c and d) shows the tube extrusion operational setup. This process is an extension of direct extrusion process where additional mandrel is needed to restrict flow of metal for production of seamless tubes. Aluminium based toothpaste and medicated tubes are produced using this process.

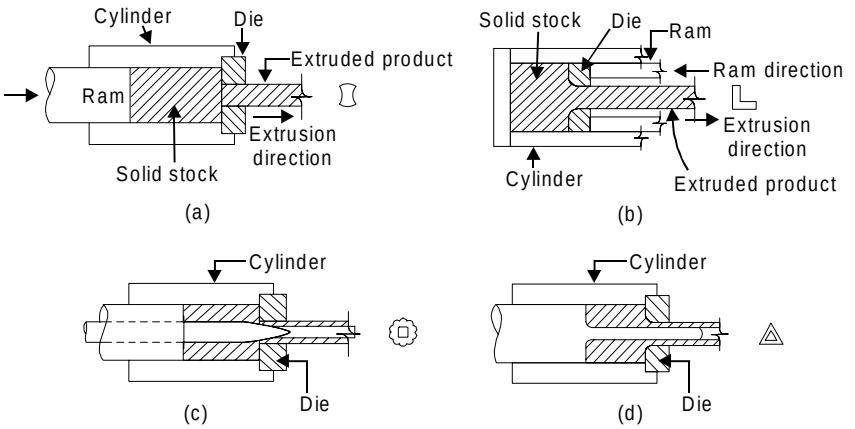


Fig. 15.4 Method of hot extrusion

15.11 HOT DRAWING

Drawing is pulling of metal through a die or a set of dies for achieving a reduction in a diameter. The material to be drawn is reduced in diameter. Fig. 15.5 is another method used in hot drawing or shaping of materials where the heated blank is placed over the die opening

the punch forces the blank through the die opening to form a cup or shell. The multiple dies are also used to accomplish the stages in drawing process. Kitchen utensils and components of food processing industries are manufactured by this process.

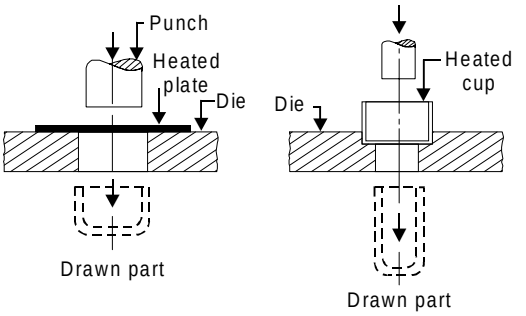


Fig. 15.5 Hot drawing

15.12 HOT SPINNING

Hot spinning is a process in which pressure and plastic flow is used to shape material. Spinning may be either hot or cold and is generally carried over a spinning lathe. In both cases, the metal is forced to flow over a rotating shape by pressure of a blunt tool as shown in Fig. 15.6. The amount of pressure of the blunt tool against the disc controls the generated heat, which helps in forming processes.

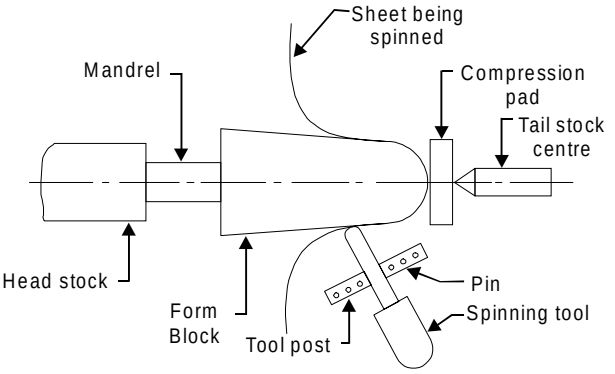


Fig. 15.6 Hot spinning

QUESTIONS

1. What do you understand by mechanical working of metals?
2. Define re-crystalline temperature.
3. Differentiate between hot and cold working.
4. Define hot working of metals. What are its advantages and disadvantages?
5. Describe with sketches the three methods of hot working.
6. Explain briefly the various methods of hot extrusion with neat sketches.

7. What is hot extrusion? In how many ways it can be performed?
8. Describe briefly with neat sketches all the process of extrusions.
9. Discuss their relative merits and demerits of different kind of extrusion.
10. How welded pipes and tubes are manufactured?
11. Describe the process of hot extrusion of tubes.
12. What is roll piercing? And for what purpose is it used?
13. Write Short notes on:
    (*a*) Hot spinning (*b*) Hot Extrusion
    (*c*) Hot forging (*d*) Hot drawing.
14. Explain hot rolling and various type of rolling mills used in hot rolling.
15. Write short notes on the following:
    (*i*) Hot piercing
    (*ii*) Hot forging
    (*iii*) Forging
16. How and why are directional properties obtained in a forged component? Discuss their advantages, dis-advantages and applications.
17. What are the advantages of hot extrusion over rolling and forging?
18. With the aid of a sketch, briefly describe the process of spinning. Why is it called a flow turning process?

16
CHAPTER

COLD WORKING

16.1 INTRODUCTION

Cold working of a metal is carried out below its recrystallisation temperature. Although normal room temperatures are ordinarily used for cold working of various types of steel, temperatures up to the recrystallisation range are sometimes used. In cold working, recovery processes are not effective.

16.2 PURPOSE OF COLD WORKING

The common purpose of cold working is given as under

1. Cold working is employed to obtain better surface finish on parts.
2. It is commonly applied to obtain increased mechanical properties.
3. It is widely applied as a forming process of making steel products using pressing and spinning.
4. It is used to obtain thinner material.

16.3 PRECAUTIONS FALLOWED IN COLD WORKING

Cold working leads to crack formation and propagation if performed in excess and it should therefore be avoided. Residual stresses developed due to inhomogeneous deformation cause warping or distortion when the part is released from the tooling and during subsequent machining. Magnitude and distribution of residual stresses should therefore be controlled. Orange-peel and stretcher strains are material related types of roughness defects found on surfaces not touched by tooling. The former can be avoided by using fine grained sheets and latter is minimized by temper rolling or stretching the strip to prevent localized yielding.

16.4 CHARACTERISTICS OF COLD WORKING

The main characteristics of cold working are given as under.

1. Cold working involves plastic deformation of a metal, which results in strain hardening.
2. It usually involves working at ordinary (room) temperatures, but, for high melting point metals, e.g., tungsten, the cold working may be carried out at a red heat.

3. The stress required for deformation increases rapidly with the amount of deformation.
4. The amount of deformation, which can be performed without introducing other treatment, is limited.
5. Cold rolling process generally distorts grain structure.
6. Good surface finish is obtained in cold rolling.
7. The upper temperature limit for cold working is the maximum temperature at which strain hardening is retained. Since cold working takes place below the recrystallisation temperature, it produces strain hardening.
8. Excessive cold working gives rise to the formation and propagation of cracks in the metal.
9. The loss of ductility during cold working has a useful side effect in machining.
10. With less ductility, the chips break more readily and facilitate the cutting operation.
11. Heating is sometimes required.
12. Directional properties can be easily imparted.
13. Spring back is a common phenomenon present in cold-working processes.
14. For relatively ductile metals, cold working is often more economical than hot working.

There is some increase and some decrease in properties of the cold worked part, which are given as under.

Cold working process increases:

- Ultimate tensile strength
- Yield strength
- Hardness
- Fatigue strength
- Residual stresses

Cold working processes decreases:

- Percentage elongation
- Reduction of area
- Impact strength
- Resistance to corrosion
- Ductility

16.4 LIMITATIONS OF COLD WORKING

1. The cold worked process possesses less ductility.
2. Imparted directional properties may be detrimental
3. Strain hardening occurs.
4. Metal surfaces must be clean and scale free before cold working.
5. Hot worked metal has to be pickled in acid to remove scale, etc.
6. Higher forces are required for deformation than those in hot working.
7. More powerful and heavier equipments are required for cold working.

16.5 ADVANTAGES OF COLD WORKING

1. In cold working processes, smooth surface finish can be easily produced.
2. Accurate dimensions of parts can be maintained.
3. Strength and hardness of the metal are increased but ductility decreased.
4. Since the working is done in cold state, no oxide would form on the surface and consequently good surface finish is obtained.
5. Cold working increases the strength and hardness of the material due to the strain hardening which would be beneficial in some situations.
6. There is no possibility of decarburization of the surface
7. Better dimensional accuracy is achieved.
8. It is far easier to handle cold parts and it is also economical for smaller sizes.

16.6 DISADVANTAGES OF COLD WORKING

1. Some materials, which are brittle, cannot be cold worked easily.
2. Since the material has higher yield strength at lower temperatures, the amount of deformation that can be given to is limited by the capability of the presses or hammers used.
3. A distortion of the grain structure is created.
4. Since the material gets strain hardened, the maximum amount of deformation that can be given is limited. Any further deformation can be given after annealing.
5. Internal stresses are set up which remain in the metal unless they are removed by proper heat-treatment.

16.7 COMPARISON OF HOT WORKING WITH COLD WORKING

The comparison of hot working with cold working is given in Table 16.1.

Table 16.1 Comparison of Hot Working with Cold Working

S. No.	Hot Working	Cold Working
1.	Hot working is carried out above the recrystallisation temperature and below the melting point. Hence the deformation of metal and recovery take place simultaneously.	Cold working is carried out below the recrystallisation temperature. As such, there is no appreciable recovery.
2.	No internal or residual stresses are set-up in the metal in hot working.	In this process internal or residual stresses are set-up in the metal.
3.	It helps in irradiating irregularities in metal composition breaking up the non metallic impurities in to tiny fragments and dispersing them through out the metal and thus facilitate uniformity of composition in the metal	It results in loss of uniformity of metal composition and thus affects the metal properties.

4.	Close tolerance can not be maintained	Better tolerance can be easily maintained.
5.	Surface finish of this process is comparatively not good	Surface finish of this process is better.
6.	It results in improvements of properties like impact strength and elongation	It results in improvements of properties like impact strength and elongation.
7.	Due to re-crystallisation and recovery no or very negligible hardening of metal takes place.	Since this is done below re-crystallisation temperature the metal gets work hardened.
8.	Due to higher deformation temperatures, the stress required for deformation is much less.	The stress required to cause deformation is much higher.
9.	Hot working refines metal grains resulting in improved mechanical properties.	Most of the cold working processes lead to distortion of grains.
10.	If cracks and blow boles are present in the metal, they are finished through hot working.	In cold working the existing cracks propagate and new cracks may develop
11.	If properly performed, it does not affect UTS, hardness, corrosion resistance, yield strength and fatigue strength of the metal.	It improves UTS, hardness, yield strength but reduces the corrosion resistance of strength of the metal.

16.8 COLD WORKING PROCESSES

Commonly employed cold working processes are:

1. Rolling
2. Extrusion
3. Wire drawing
4. Forging
5. Sheet metal operations
   - (*a*) Shearing etc.
     - (*i*) Piercing
     - (*ii*) Blanking
     - (*iii*) Cutting
     - (*iv*) Parting
     - (*v*) Punching
     - (*vi*) Notching
     - (*vii*) Slitting
     - (*viii*) Nibbling
     - (*ix*) Lancing
     - (*x*) Trimming
   - (*b*) Bending
   - (*c*) Drawing
   - (*d*) Pressing and deep drawing
   - (*e*) Squeezing
     - (*i*) Embossing
     - (*ii*) Coining
6. Cold spinning
7. Shot peening

Cold working processes are also similar to hot working processes. Some of the important colds working processes are described as under.

16.9 COLD-ROLLING

Cold rolling process setup is similar to hot rolling. Bars of all shapes such as rods, sheets and strips are commonly finished by rolling. Foil is made of the softer metals in this way. Cold-rolling metals impart smooth bright surface finish and in good physical and mechanical properties to cold rolled parts. If the objective is only to give a clean, smooth finishing metal, only a superficial amount of rolling will be needed. On the other hand, where it is desirable that the tensile strength and stiffness be increased substantially, the section thickness is significantly reduced, and then higher roll pressures and deeper kneading are necessary. Cold rolling also improves machinability in the cold rolled part by conferring the property of brittleness, a condition, which is conducive to smooth tool, finishes with broken chips. The preliminary step to the cold-rolling operation, the sheets of pre hot-rolled steel are immersed in an acid solution to remove the washed in water and then dried. The cleaned steel is passed through set of rolls of cold rolling process thereby producing a slight reduction in each the required thickness is obtained.

The arrangement of rolls in a rolling mill, also called rolling stand, varies depending on the application. The various possible configurations of rolls are similar to hot rolling. The names of the rolling stand arrangements are generally given by the number of rolls employed. These stands are more expensive compared to the non-reversible type because of the reversible drive needed. Internal stresses are set up in cold rolled parts which remain in the metal unless they are removed by proper heat-treatment. This process needs more power for accomplishing the operation in comparison to hot rolling.

16.10 COLD EXTRUSION

Principle of cold extrusion is similar to that of hot extrusion, which has been discussed under hot extrusion in section 15.10. The dissimilarity is that material in hot working processes should possess the essential ductility with out the application of heat. Impact extrusion is also a cold extrusion process. It is used for making small components from ductile materials. Impact extrusion process is shown in Fig. 16.1. Impact extrusion of material is accomplished where the work blank is placed in position over the die opening the punch forces the blank through the die opening causing material to flow plastically around the punch. The outside diameter of the tube is same as diameter of the die, and the thickness is controlled by the clearance between punch and die. Collapsible medicare tubes and toothpastes etc. are produced using this impact extrusion.

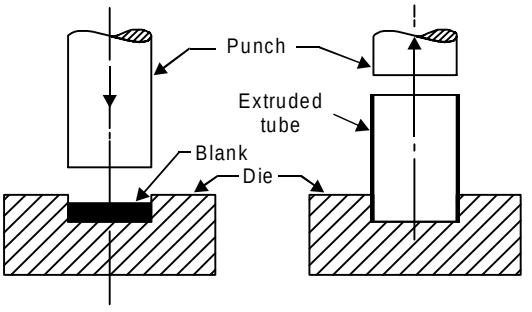


Fig. 16.1 Impact extrusion

16.11 WIRE DRAWING

The wire drawing die setup is shown in Fig.16.2(a). The process of producing the wires of different diameters is accomplished by pulling a wire through a hardened die usually made up carbide. However a smaller diameter wires are drawn through a die made of diamond. The larger diameter oriented wire is first cleaned, pickled, washed and then lubricated. Cleaning is essentially done to remove any scale and rust present on the surface, which may severely affect the die. It is normally done by acid pickling. The hot rolled steel is descaled, pickled in acid, washed in water and coated with lime and other lubricants. To make for an easier entrance of wire into the die, the end of the stock is made pointed to facilitate the entry. A pointed or reduced diameter at the end of wire duly lubricated is pushed or introduced through the die which is water cooled also. This pointing is done by means of rotary swaging or by simple hammering. It is then gripped and pulled for attaching it to a power driven reel. The wire diameter is reduced in die because of the ductility property of the material to the smaller diameter through one set of die. However for more reduction in diameter of the wire, various sets of dies can be used in line for subsequent reduction in diameter at each stage as shown in Fig 16.2(b). The reduction in each pass through the die range about 10% for steel and 40% for ductile materials such as copper.

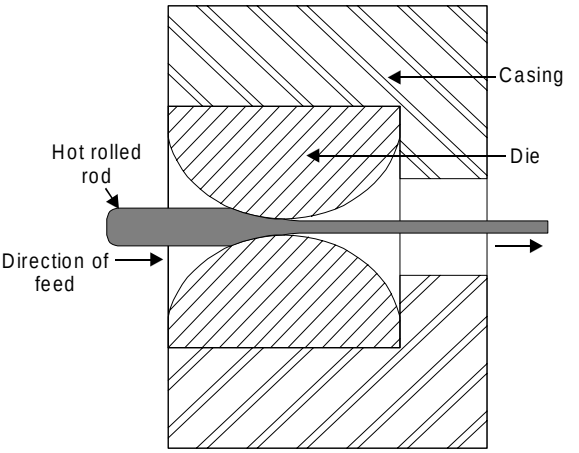


Fig. 16.2(a) Wire drawing

The drawing of the wire starts with a rod or coil of hot rolled steel, which is 0.8 to 1.6 mm larger than the final size required. In this process, there is no force is applied for pushing the wire into the die from the entrance side. The material should be sufficiently ductile since it is pulled by the tensile forces. Hence, the wire may have to be annealed properly to provide the necessary ductility. Further, the wire is to go through the conical portion and then pulled out through the exit by the gripper. The other aspect of preparation needed is the cleaning of the wire and lubricating it as it flows through the die. The pressures acting at the interface of the die and the metal being very high, the lubrication of the die is a serious problem. Therefore, to carry the lubricant through the die, special methods such as gulling, coppering, phosphating and liming are used. The wire is coated with a thin coat of ferrous hydroxide which when combined with lime acts as filler for the lubricant. This process is called sulling. In phosphating, a thin film of manganese, iron or zinc phosphate is applied on the wire, which makes the lubricant to stick to the wire, thereby reducing the friction and consequently, the drawing load. Another lubricant vehicle that is used in wire drawing is a coating of lime. After acid pickling, lime is applied and then allowed to dry. The lime neutralizes any amount of acid left on the surface and adsorbs the lubricant for carrying it to the die. The lubricant normally used is the soap solution. For very thin wires, electrolytic coating of copper is used to reduce friction. The dies used for wire drawing are severely affected because of high stresses and abrasion. The various die materials that are used are chilled cast iron, tool steels, tungsten carbide and diamond. The cast iron dies are used for small runs. For very large sizes, alloy

steels are used in making the dies. The tungsten carbide dies are used most commonly for medium size wires and large productions. The tungsten carbide dies are referred because of their long life that is 2 to 3 times that of alloy steel dies. For very fine wires, diamond dies are used. Wire drawing improves the mechanical properties because of the cold working. The material loses its ductility during the wire drawing process and when it is to be repeatedly drawn to bring it to the final size, intermediate annealing is required to restore the ductility.

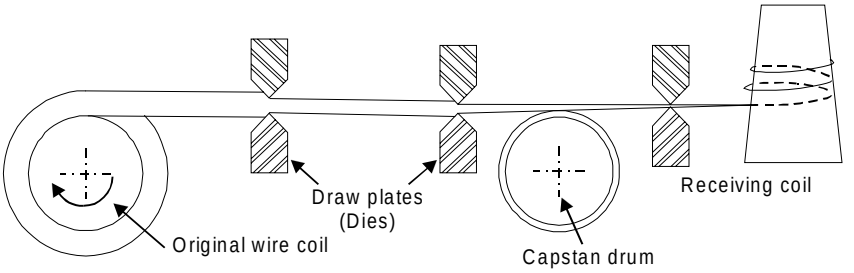


Fig. 16.2(b) Wire drawing

16.12 SHEET METAL PROCESSES

Sheet metal work processing is highly common in manufacturing sheet metal parts using from sheet stock. The various sheet metal operations are performed on press machine of required capacity using press tools or dies. The dies may be single operation die or multi-operation dies. A simple piercing, blanking and shearing die is shown in Fig. 16.3. However the basic sheet metal operations are described in the following lines.

16.12.1 General Sheet Metal Operations

Shearing

It takes place when punch and die are used. The quality of the cut surface is greatly influenced by the clearance between the two shearing edges. However, the basic shearing operations are described in the following lines.

Cutting

It means severing a piece from a strip with a cut along a single line.

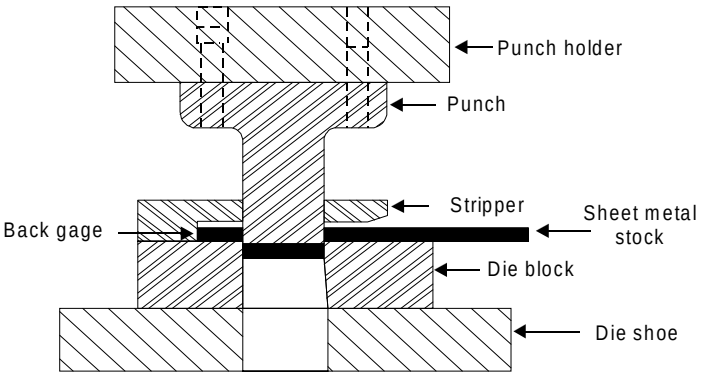


Fig. 16.3 Typical simple press tool

Parting

It signifies that scrap is removed between the two pieces to part them.

Blanking

It means cutting a whole piece from sheet metal just enough scrap is left all around the opening to assure that the punch has metal to cut along its entire edge. The piece detached from the strip is known as blank and is led for further operations. The remaining metal strip is scrap. Blanking is nearly almost the first operation and may be the only one necessary or it may be followed successively by many others. Blanking is often combined with other operations in one tool, all the work being performed at one stroke of the press. A blanking die must have clearance, otherwise the blank would not fall freely, and it might remain struck in the die block.

Punching

It is the operation of producing circular holes on a sheet metal by a punch and die. The material punched out is removed as waste. Piercing, on the other hand, is the process of producing holes of any desired shape.

Notching

It is a process of removing metal to the desired shape from the side or edge of a sheet or strip.

Slitting

When shearing is conducted between rotary blades, the process is referred to as slitting. It cuts the sheet metal lengthwise.

Nibbling

It is an operation of cutting any shape from sheet metal without special tools. It is done on a nibbling machine.

Trimming

It is the operation of cutting away excess metal in a flange or flash from a piece.

Lancing

It makes a cut part way across a strip.

Forming

It is a metal working process in which the shape of the punch and the die is directly reproduced in the metal with little or no metal flow.

16.12.2 Bending

It is employed for bending into desired shapes various stock materials like sheets, rods, wires, bars, pipes, tubes and various structural shapes. Formed dies are used for bending the articles and the operation is usually performed in many stages. For bending in all sheet material are stressed beyond the elastic limit in tension on the outside and in compression on the inside of the bend. There is only one line, the natural line which retains its original length. The neutral axis lies at a distance of 30 to 50% of thickness of the sheet from the inside of the bend. Stretching of the sheet metal on the outside makes the stock thinner. Bending is sometimes called as forming which involves angle bending, roll bending, and roll forming and

seaming and spinning. Well designed fixtures are also used where mass bending of such components is required. Bending occurs when forces are applied to localized areas, such as in bending a piece of metal into a right angle, and forming occurs when complete items or parts are shaped. However, some common kinds of sheet metal bends using by press brake dies are depicted in Fig. 16.4.

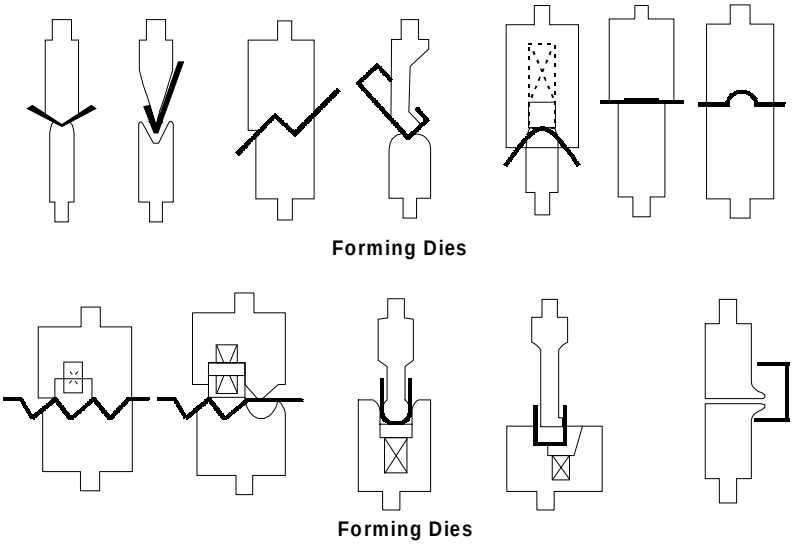


Fig. 16.4 Kinds of sheet metal bends using press brake dies

16.12.3 Cold Drawing

Like hot drawing, it also involves the forcing of a metal through by means of a tensile force applied to the exit side of the drawing die. Most of the plastic flow is accomplished by the compressive force which arises from the reaction of metal with die. It is the operation in which the metal is made to flow plastically by applying tensile stresses to the metal. The blank of calculated diameter is placed on a die and held of it by a blank holder and bottom is pressed into the die by a punch and the walls are pulled in as shown in Fig. 16.5. The efficiency of operation depends upon blank size, reduction factor, drawing pressure, blank holding pressure, punch and die diameters, type of lubricant, die material etc. Therefore, this process is generally used for making cup shaped parts from the sheet blanks, without excessive wrinkling, thinning and fracturing. It can undertake jobs of nearly any size. It is a process of managing a flat precut metal blank into a hollow vessel. Utensils of stainless steel are generally made by this process.

16.12.3.1 Metal Flow in Deep Drawing Dies

When the punch of a deep drawing press forces a portion of metal blank through the bore of the drawing, different forces came into action to cause a rather complicated plastic flow of the material. The volume and thickness of the metal remain essentially constant, and the final shape of the cup will be similar to the contour of the punch. The flow of metal is summarized as follows.

(*i*) There is no metal deformation takes place in the blank area which forms the bottom of the cup.

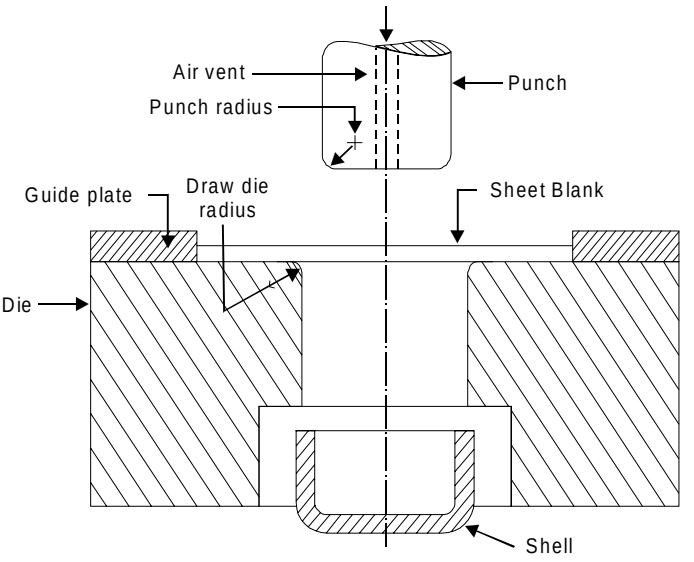


Fig. 16.5 Cold drawing

(*ii*) The metal flow of the volume elements at the periphery of the blank is extensive and involves an increase in metal thickness caused by severe circumferential compression. The increase is usually slight because it is restricted by the clearance between the punch and bore wall of the die ring.

(*iii*) The metal flow taking place during the forming of the cup will uniformly increases with cup height.

Fig. 16.6 shows the flow of metal in deep drawing.

16.12.4 Embossing

Fig. 16.7 shows the embossing process. It is a process through which blanks of sheet metal are stretched to shape under pressure by means of a punch and a die. Punch operates at a low speed to allow time for proper stretching. The operation gives a stiffening effect to the metal being embossed. Stress in the material may be reduced by producing deep parallel ridges. A large number of ornamental wares, such as plates in sheet metal are produced. A simple form of this process, called open embossing, consists of producing simple shallow shapes by the punch only.

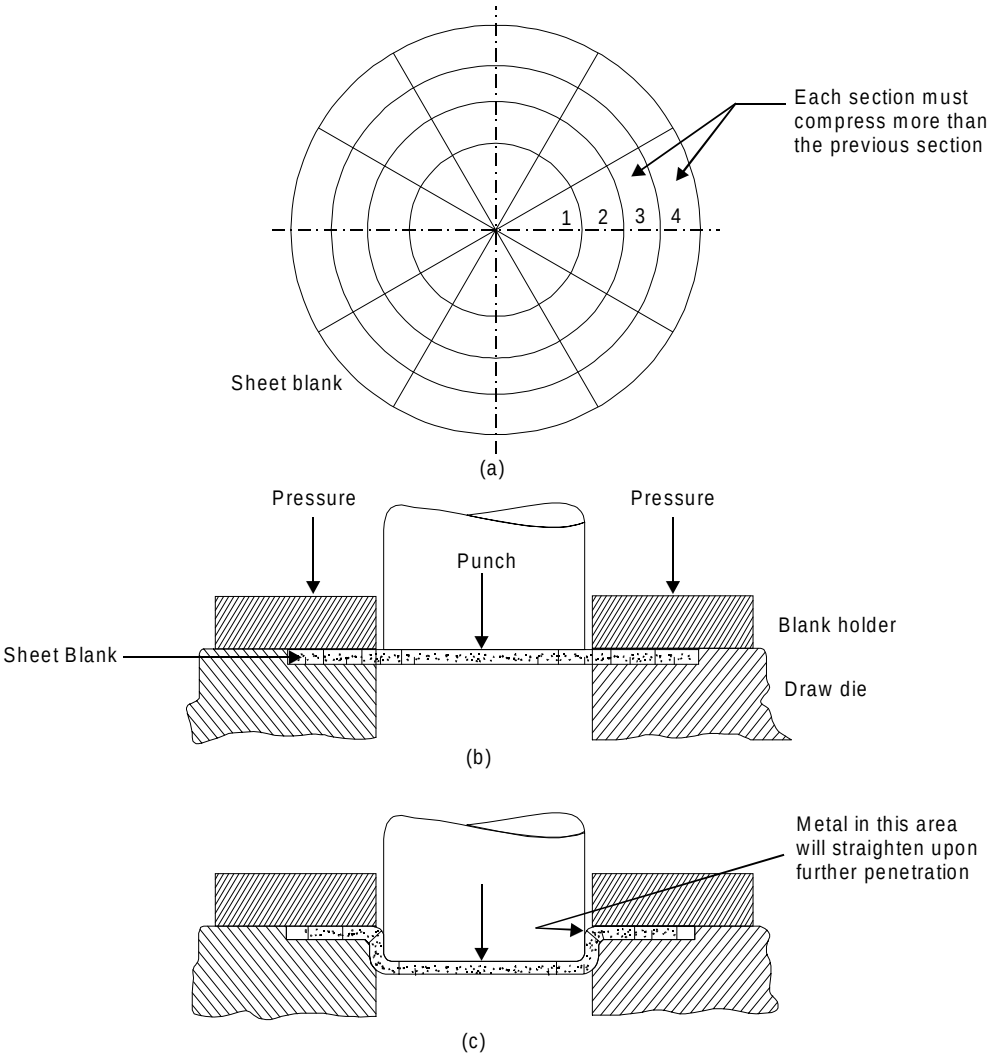


Fig. 16.6 Metal flow in deep drawing

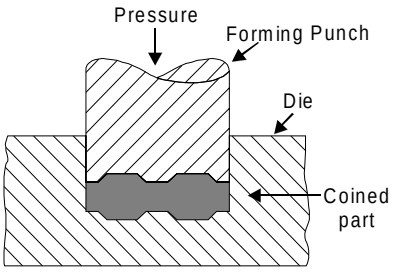


Fig. 16.7 Embossing

16.12.5 Coining

Fig 16.8 shows the coining process used in cold working operations. It is basically a cold working operation, which is performed in dies where the metal blank is confined and its lateral flow is restricted. It is mainly used for production of important articles such as medals, coins, stickers and other similar articles, which possess shallow configurations on their surfaces. The operation involves placing a metal slug in the die and applying heavy pressure by the punch. The metal flows plastically and is squeezed to the shape between punch and the die. The process, on account of the very high pressures required, can be employed only for soft metals with high plasticity.

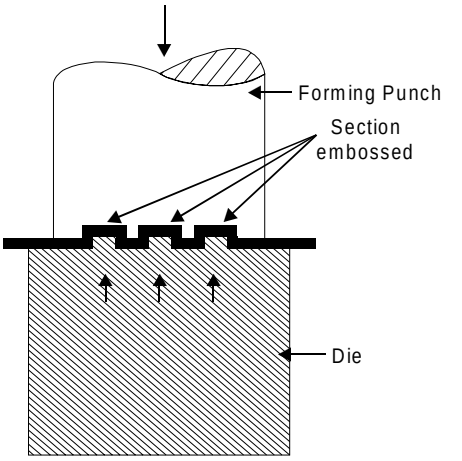


Fig. 16.8 Coining

16.12.6 Roll Forming

It consists of feeding a continuous metal sheet or strip through a series of rolls whereby it is formed into desired shapes. The roll formed sections can be used in as formed condition with their both edges separate from each other. Alternatively, they can be welded to form a closed section such as tubing and pipes. A number of rolls employed in the series depend upon the shape to be formed. The forming arrangement carries guide rolls and straightening devices also.

16.13 SHOT PEENING

It is a process of increasing the hardness and fatigue strength on parts surfaces. The process comprises of throwing a blast of metal shot on to the surface of a component requiring shot peening. It is used to set up a superficial state of surface compression stress, causing the interior of the member to assume an opposite tensile stress. Blast may be thrown either by air pressure or with help of a wheel revolving at high speed. This high velocity blast of metal shot provides a sort of compression over the components surface and increases hardness and strength of the surface and also its fatigue resistance.

16.14 QUESTIONS

1. Differentiate between hot working and cold working.
2. Define cold working of metals. What are its advantages and disadvantages?
3. What are the specific advantages, limitations and applications of cold working?
4. Explain the various cold drawing processes.
5. Using neat sketches explain briefly the process of wire-drawing.
6. Describe the process of cold spinning stating its advantages and specific uses.
7. Explain briefly the stretch forming operation.
8. Write short notes on the cold rolling and cold extrusion.
9. What is cold forging and swaging?
10. What for cold heading is used?
11. Explain the process of rotary swaging with the help of a neat sketch.

12. What is impact extrusion? Explain this process and state its specific applications.
13. Describe the following cold working processes:
    (*i*) Embossing
    (*ii*) Coining
    (*iii*) Roll forming
    (*iv*) Roll bending
    (*v*) Shot peening
14. Explain the following cold working processes:
    (*i*) Cold rolling
    (*ii*) Stretch forming
    (*iii*) Cold hobbing
    (*iv*) Cold bending.
15. Write short notes on the following:
    (*i*) Cold forging
    (*ii*) Hobbing
    (*iii*) Embossing
    (*iv*) Staking
    (*v*) Ironing
    (*vi*) Shot peening.
16. Discuss the methods used for the production of pipes and tubes.
17. Using neat sketch describe briefly the method of extruding a hollow round collapsible tube with help of drawing process.

17
CHAPTER

WELDING

17.1 INTRODUCTION

Welding is a process for joining two similar or dissimilar metals by fusion. It joins different metals/alloys, with or without the application of pressure and with or without the use of filler metal. The fusion of metal takes place by means of heat. The heat may be generated either from combustion of gases, electric arc, electric resistance or by chemical reaction. During some type of welding processes, pressure may also be employed, but this is not an essential requirement for all welding processes. Welding provides a permanent joint but it normally affects the metallurgy of the components. It is therefore usually accompanied by post weld heat treatment for most of the critical components. The welding is widely used as a fabrication and repairing process in industries. Some of the typical applications of welding include the fabrication of ships, pressure vessels, automobile bodies, off-shore platform, bridges, welded pipes, sealing of nuclear fuel and explosives, etc.

Most of the metals and alloys can be welded by one type of welding process or the other. However, some are easier to weld than others. To compare this ease in welding term 'weldability' is often used. The weldability may be defined as property of a metal which indicates the ease with which it can be welded with other similar or dissimilar metals. Weldability of a material depends upon various factors like the metallurgical changes that occur due to welding, changes in hardness in and around the weld, gas evolution and absorption, extent of oxidation, and the effect on cracking tendency of the joint. Plain low carbon steel (C-0.12%) has the best weldability amongst metals. Generally it is seen that the materials with high castability usually have low weldability.

17.2 TERMINOLOGICAL ELEMENTS OF WELDING PROCESS

The terminological elements of welding process used with common welding joints such as base metal, fusion zone, weld face, root face, root opening toe and root are depicted in Fig. 17.1

17.2.1 Edge preparations

For welding the edges of joining surfaces of metals are prepared first. Different edge preparations may be used for welding butt joints, which are given in Fig 17.2.

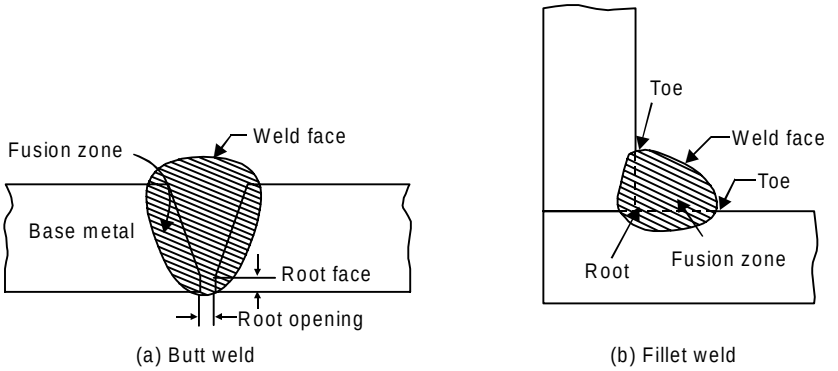


Fig. 17.1 Terminological elements of welding process

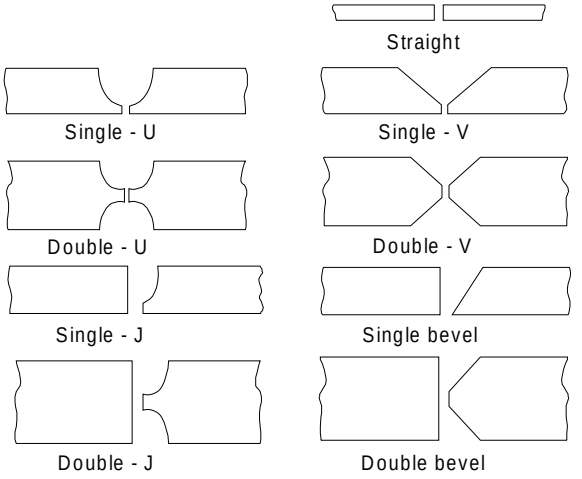


Fig. 17.2 Butt welding joints edge preparations

17.2.2 Welding joints

Some common welding joints are shown in Fig. 17.3. Welding joints are of generally of two major kinds namely lap joint and butt joint. The main types are described as under.

17.2.2.1 Lap weld joint

Single-Lap Joint

This joint, made by overlapping the edges of the plate, is not recommended for most work. The single lap has very little resistance to bending. It can be used satisfactorily for joining two cylinders that fit inside one another.

Double-Lap Joint

This is stronger than the single-lap joint but has the disadvantage that it requires twice as much welding.

Tee Fillet Weld

This type of joint, although widely used, should not be employed if an alternative design is possible.

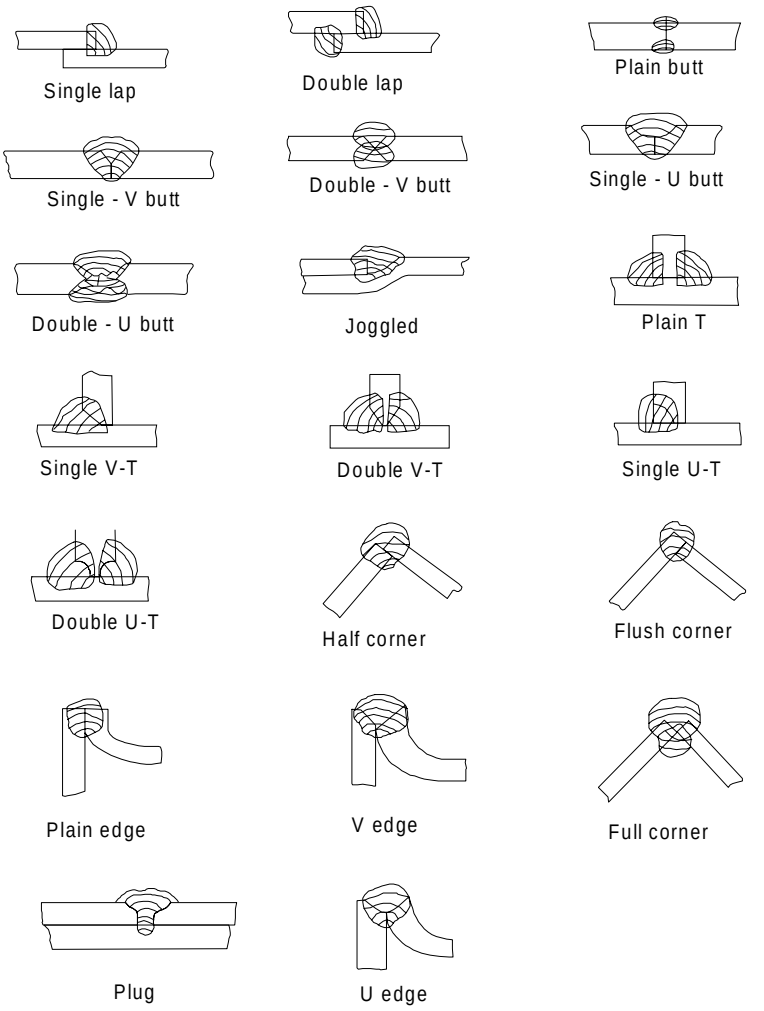


Fig. 17.3 Types of welding joints

17.2.2.2 Butt weld joint

Single-Vee Butt Weld

It is used for plates up to 15.8 mm thick. The angle of the vee depends upon the technique being used, the plates being spaced approximately 3.2 mm.

Double-Vee Butt Weld

It is used for plates over 13 mm thick when the welding can be performed on both sides of the plate. The top vee angle is either 60° or 80°, while the bottom angle is 80°, depending on the technique being used.

17.2.3 Welding Positions

As shown in Fig. 17.4, there are four types of welding positions, which are given as:

1. Flat or down hand position

2. Horizontal position
3. Vertical position
4. Overhead position

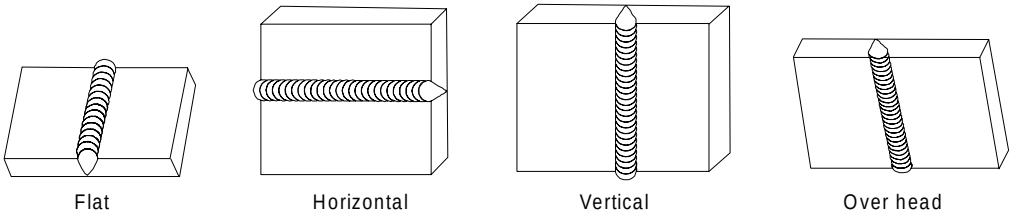


Fig. 17.4 Kinds of welding positions

17.2.3.1 Flat or Downhand Welding Position

The flat position or down hand position is one in which the welding is performed from the upper side of the joint and the face of the weld is approximately horizontal. This is the simplest and the most convenient position for welding. Using this technique, excellent welded joints at a fast speed with minimum risk of fatigue to the welders can be obtained.

17.2.3.2 Horizontal Welding Position

In horizontal position, the plane of the workpiece is vertical and the deposited weld head is horizontal. The metal deposition rate in horizontal welding is next to that achieved in flat or downhand welding position. This position of welding is most commonly used in welding vessels and reservoirs.

17.2.3.3 Veritical Welding Position

In vertical position, the plane of the workpiece is vertical and the weld is deposited upon a vertical surface. It is difficult to produce satisfactory welds in this position due to the effect of the force of gravity on the molten metal. The welder must constantly control the metal so that it does not run or drop from the weld. Vertical welding may be of two types viz., vertical-up and vertical-down. Vertical-up welding is preferred when strength is the major consideration. The vertical-down welding is used for a sealing operation and for welding sheet metal.

17.2.3.4 Overhead Welding Position

The overhead position is probably even more difficult to weld than the vertical position. Here the pull of gravity against the molten metal is much greater. The force of the flame against the weld serves to counteract the pull of gravity. In overhead position, the plane of the workpiece is horizontal. But the welding is carried out from the underside. The electrode is held with its welding end upward. It is a good practice to use very short arc and basic coated electrodes for overhead welding.

17.3 ADVANTAGES AND DISADVANTAGES OF WELDING

Advantages

1. Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.)

2. Welding, if properly controlled results permanent joints having strength equal or sometimes more than base metal.
3. Large number of metals and alloys both similar and dissimilar can be joined by welding.
4. General welding equipment is not very costly.
5. Portable welding equipments can be easily made available.
6. Welding permits considerable freedom in design.
7. Welding can join welding jobs through spots, as continuous pressure tight seams, end-to-end and in a number of other configurations.
8. Welding can also be mechanized.

Disadvantages

1. It results in residual stresses and distortion of the workpieces.
2. Welded joint needs stress relieving and heat treatment.
3. Welding gives out harmful radiations (light), fumes and spatter.
4. Jigs, and fixtures may also be needed to hold and position the parts to be welded
5. Edges preparation of the welding jobs are required before welding
6. Skilled welder is required for production of good welding
7. Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

17.4 CLASSIFICATION OF WELDING AND ALLIED PROCESSES

There are different welding, brazing and soldering methods are being used in industries today. There are various ways of classifying the welding and allied processes. For example, they may be classified on the basis of source of heat, i.e., blacksmith fire, flame, arc, etc. and the type of interaction i.e., liquid / liquid (fusion welding) or solid/solid (solid state welding). Welding processes may also be classified in two categories namely plastic (forge) and fusion. However, the general classification of welding and allied processes is given as under

(A) Welding Processes

1. Oxy-Fuel Gas Welding Processes

1 Air-acetylene welding
2 Oxy-acetylene welding
3 Oxy-hydrogen welding
4 Pressure gas welding

2. Arc Welding Processes

1. Carbon Arc Welding
2. Shielded Metal Arc Welding
3. Submerged Arc Welding
4. Gas Tungsten Arc Welding

5. Gas Metal Arc Welding
6. Plasma Arc Welding
7. Atomic Hydrogen Welding
8. Electro-slag Welding
9. Stud Arc Welding
10. Electro-gas Welding

3. Resistance Welding

1. Spot Welding
2. Seam Welding
3. Projection Welding
4. Resistance Butt Welding
5. Flash Butt Welding
6. Percussion Welding
7. High Frequency Resistance Welding
8. High Frequency Induction Welding

4. Solid-State Welding Processes

1. Forge Welding
2. Cold Pressure Welding
3. Friction Welding
4. Explosive Welding
5. Diffusion Welding
6. Cold Pressure Welding
7. Thermo-compression Welding

5. Thermit Welding Processes

1. Thermit Welding
2. Pressure Thermit Welding

6. Radiant Energy Welding Processes

1. Laser Welding
2. Electron Beam Welding

(B) Allied Processes

1. Metal Joining or Metal Depositing Processes

1. Soldering
2. Brazing
3. Braze Welding
4. Adhesive Bonding

5. Metal Spraying
6. Surfacing

2. Thermal Cuting Processes

1. Gas Cutting
2. Arc Cutting

Some of the important and widely used welding processes are discussed in the rest of this chapter.

17.5 GAS WELDING PROCESSES

A fusion welding process which joins metals, using the heat of combustion of an oxygen /air and fuel gas (i.e. acetylene, hydrogen propane or butane) mixture is usually referred as 'gas welding'. The intense heat (flame) thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal. Operation of gas welding is shown in Fig. 17.5. The fuel gas generally employed is acetylene; however gases other than acetylene can also be used though with lower flame temperature. Oxy-acetylene flame is the most versatile and hottest of all the flames produced by the combination of oxygen and other fuel gases. Other gases such as Hydrogen, Propane, Butane, Natural gas etc., may be used for some welding and brazing applications.

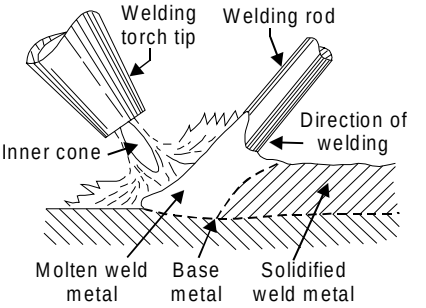


Fig. 17.5 Gas welding operation

17.5.1 Oxy-Acetylent Welding

In this process, acetylene is mixed with oxygen in correct proportions in the welding torch and ignited. The flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal. The oxy-acetylene flame reaches a temperature of about 3300°C and thus can melt most of the ferrous and non-ferrous metals in common use. A filler metal rod or welding rod is generally added to the molten metal pool to build up the seam slightly for greater strength.

17.5.1.1 Types of Welding Flames

In oxy-acetylene welding, flame is the most important means to control the welding joint and the welding process. The correct type of flame is essential for the production of satisfactory welds. The flame must be of the proper size, shape and condition in order to operate with maximum efficiency. There are three basic types of oxy-acetylene flames.

1. Neutral welding flame (Acetylene and oxygen in equal proportions).

2. Carburizing welding flame or reducing (excess of acetylene).
3. Oxidizing welding flame (excess of oxygen).

The gas welding flames are shown in Fig 17.6.

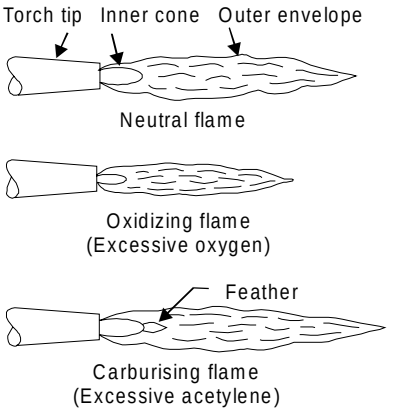


Fig. 17.6 Gas welding flames

Neutral Welding Flame

A neutral flame results when approximately equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip. The temperature of the neutral flame is of the order of about 5900°F (3260°C). It has a clear, well defined inner cone, indicating that the combustion is complete. The inner cone is light blue in color. It is surrounded by an outer flame envelope, produced by the combination of oxygen in the air and superheated carbon monoxide and hydrogen gases from the inner cone. This envelope is Usually a much darker blue than the inner cone. A neutral flame is named so because it affects no chemical change on the molten metal and, therefore will not oxidize or carburize the metal. The neutral flame is commonly used for the welding of mild steel, stainless steel, cast Iron, copper, and aluminium.

Carburising or Reducing Welding Flame

The carburizing or reducing flame has excess of acetylene and can be recognized by acetylene feather, which exists between the inner cone and the outer envelope. The outer flame envelope is longer than that of the neutral flame and is usually much brighter in color. With iron and steel, carburizing flame produces very hard, brittle substance known as iron carbide. A reducing flame may be distinguished from carburizing flame by the fact that a carburizing flame contains more acetylene than a reducing flame. A reducing flame has an approximate temperature of 3038°C. A carburizing-flame is used in the welding of lead and for carburizing (surface hardening) purpose. A reducing flame, on the other hand, does not carburize the metal; rather it ensures the absence of the oxidizing condition. It is used for welding with low alloy steel rods and for welding those metals, (e.g., non-ferrous) that do not tend to absorb carbon. This flame is very well used for welding high carbon steel.

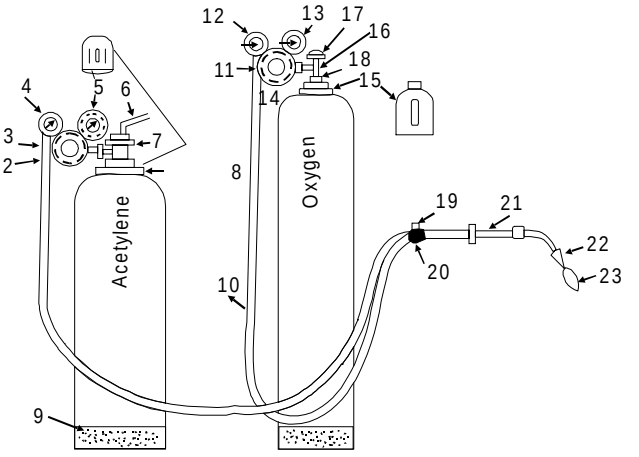
Oxidising Welding flame

The oxidizing flame has an excess of oxygen over the acetylene. An oxidizing flame can be recognized by the small cone, which is shorter, much bluer in color and more pointed than that of the neutral flame. The outer flame envelope is much shorter and tends to fan out at

the end. Such a flame makes a loud roaring sound. It is the hottest flame (temperature as high as 6300°F) produced by any oxy-fuel gas source. But the excess oxygen especially at high temperatures tends to combine with many metals to form hard, brittle, low strength oxides. Moreover, an excess of oxygen causes the weld bead and the surrounding area to have a scummy or dirty appearance. For these reasons, an oxidizing flame is of limited use in welding. It is not used in the welding of steel. A slightly oxidizing flame is helpful when welding (*i*) Copper-base metals (*ii*) Zinc-base metals and (*iii*) A few types of ferrous metals such as manganese steel and cast iron. The oxidizing atmosphere in these cases, create a base-metal oxide that protects the base metal.

17.5.1.2 Gas Welding Equipments

An arrangement of oxy acetylene welding set up is shown in Fig.17.7. The basic tools and equipments used for oxy-acetylene welding are following:



1. Acetylene hose
2. Adjusting screw
3. Acetylene regulator
4. Regulator outlet pressure gauge
5. Cylinder pressure gauge
6. Valve wrench
7. Acetylene cylinder valve
8. Cylinder cap
9. Fusible plugs
10. Oxygen hose
11. Oxygen regulator
12. Regulator outlet pressure gauge
13. Cylinder pressure gauge
14. Cylinder cap
15. Oxygen cylinder valve
16. Oxygen cylinder valve
17. Hand wheel
18. Bursting disc
19. Acetylene valve
20. Oxygen valve
21. Welding torch
22. Torch tip
23. Flame

Fig. 17.7 Oxy acetylene welding set up

Acetylene and oxygen gas is stored in compressed gas cylinders. These gas cylinders differ widely in capacity, design and colour code. However, in most of the countries, the standard size of these cylinders is 6 to 7 m^3 and is painted black for oxygen and maroon for acetylene. An acetylene cylinder is filled with some absorptive material, which is saturated with a chemical solvent acetone. Acetone has the ability to absorb a large volume of acetylene and release it as the pressure falls. If large quantities of acetylene gas are being consumed, it is much cheaper to generate the gas at the place of use with the help of acetylene gas generators. Acetylene gas is generated by carbide-to-water method.

Oxygen gas cylinders are usually equipped with about 40 litres of oxygen at a pressure of about 154 Kgf/cm^2 at 21°C. To provide against dangerously excessive pressure, such as

could occur if the cylinders were exposed to fire, every valve has a safety device to release the oxygen before there is any danger of rupturing the cylinders. Fragile discs and fusible plugs are usually provided in the cylinders valves in case it is subjected to danger.

Gas pressure regulators

Gas pressure regulators are employed for regulating the supply of acetylene and oxygen gas from cylinders. A pressure regulator is connected between the cylinder and hose leading to welding torch. The cylinder and hose connections have left-handed threads on the acetylene regulator while these are right handed on the oxygen regulator. A pressure regulator is fitted with two pressure gauges, one for indication of the gas pressure in the cylinder and the other for indication of the reduced pressure at which the gas is going out.

Welding torch

Fig 17.8 shows the construction of the welding torch. It is a tool for mixing oxygen and acetylene in correct proportion and burning the mixture at the end of a tip. Gas flow to the torch is controlled with the help of two needle valves in the handle of the torch. There are two basic types of gas welding torches:

(1) Positive pressure (also known as medium or equal pressure), and

(2) Low pressure or injector type

The positive pressure type welding torch is the more common of the two types of oxy-acetylene torches.

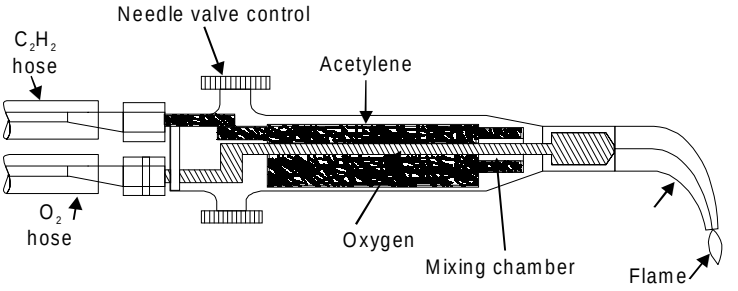


Fig. 17.8 Welding torch

Torch tips

It is the portion of the welding apparatus through which the gases pass just prior to their ignition and burning. A great variety of interchangeable welding tips differing in size, shape and construction are available commercially. The tip sizes are identified by the diameter of the opening. The diameter of the tip opening used for welding depends upon the type of metal to be welded.

Hose pipes

The hose pipes are used for the supply of gases from the pressure regulators. The most common method of hose pipe fitting both oxygen and acetylene gas is the reinforced rubber hose pipe. Green is the standard color for oxygen hose, red for acetylene, and black hose for other industrially available welding gases.

Goggles

These are fitted with colored lenses and are used to protect the eyes from harmful heat and ultraviolet and infrared rays.

Gloves

These are required to protect the hands from any injury due to the heat of welding process.

Spark-lighter

It is used for frequent igniting the welding torch.

Filler rods

Gas welding can be done with or without using filler rod. When welding with the filler rod, it should be held at approximately 900 to the welding tip. Filler rods have the same or nearly the same chemical composition as the base metal. Metallurgical properties of the weld deposit can be controlled by the optimum choice of filler rod. Most of the filler rods for gas welding also contain deoxidizers to control the oxygen content of weld pool.

Fluxes

Fluxes are used in gas welding to remove the oxide film and to maintain a clean surface. These are usually employed for gas welding of aluminium, stainless steel, cast iron, brass and silicon bronze. They are available in the market in the form of dry powder, paste, or thick solutions.

17.5.2 Safety Recommendations for Gas Welding

Welding and cutting of metals involve the application of intense heat to the objects being welded or cut. This intense heat in welding is obtained from the use of inflammable gases, (e.g. acetylene, hydrogen, etc.) or electricity. The intense welding heat and the sources employed to produce it can be potentially hazardous. Therefore, to protect persons from injury and to protect building and equipment against fire, etc., a set of recommendations concerning safety and health measures for the welders and those concerned with the safety of the equipments etc., have been published by BIS and many other similar but International organizations. By keeping in mind these recommendations or precautions, the risks associated with welding can be largely reduced. Therefore, it is suggested that the beginner in the field of gas welding must go through and become familiar with these general safety recommendations, which are given below.

1. Never hang a torch with its hose on regulators or cylinder valves.
2. During working, if the welding tip becomes overheated it may be cooled by plunging the torch into water; close the acetylene valve but leave a little oxygen flowing.
3. Always use the correct pressure regulators for a gas. Acetylene pressure regulator should never be used with any other gas.
4. Do not move the cylinder by holding the pressure regulator and also handle pressure regulators carefully.
5. Use pressure regulator only at pressures for which it is intended.
6. Open cylinder valves slowly to avoid straining the mechanism of pressure regulator.
7. Never use oil, grease or lubricant of any kind on regulator connections.

8. For repairs, calibrations and adjustments purposes, the pressure regulators should be sent to the supplier.
9. Do cracking before connecting pressure regulator to the gas cylinder.
10. Inspect union nuts and connections on regulators before use to detect faulty seats which may cause leakage of gas when the regulators are attached to the cylinder valves.
11. Hose connections shall be well fittings and clamped properly otherwise securely fastened to these connections in such a manner as to withstand without leakage a pressure twice as great as the maximum delivery pressure of the pressure regulators provided on the system.
12. Protect the hose from flying sparks, hot slag, hot workpiece and open flame. If dirt goes into hose, blow through (with oxygen, not acetylene) before coupling to torch or regulator.
13. Store hose on a reel (an automobile wheel) when not in use.
14. Never allow the hose to come into contact with oil or grease; these deteriorate the rubber and constitute a hazard with oxygen.
15. Use the correct color hose for oxygen (green/black) and acetylene (red) and never use oxygen hose for acetylene or vice versa.
16. Always protect hose from being trampled on or run over. Avoid tangle and kinks. Never leave the hose so that it can be tripped over.

Hazards of fumes, gases and dusts can be minimized by (i) improving general ventilation of the place where welding is carried out (ii) using local exhaust units, and (iii) wearing individual respiratory protective equipment.

17.6 ARC WELDING PROCESSES

The process, in which an electric arc between an electrode and a workpiece or between two electrodes is utilized to weld base metals, is called an arc welding process. The basic principle of arc welding is shown in Fig 17.9(a). However the basic elements involved in arc welding process are shown in Fig. 17.9(b). Most of these processes use some shielding gas while others employ coatings or fluxes to prevent the weld pool from the surrounding atmosphere. The various arc welding processes are:

1. Carbon Arc Welding
2. Shielded Metal Arc Welding
3. Flux Cored Arc Welding
4. Gas Tungsten Arc Welding
5. Gas Metal Arc Welding
6. Plasma Arc Welding
7. Atomic Hydrogen Welding
8. Electroslag Welding
9. Stud Arc Welding
10. Electrogas Welding

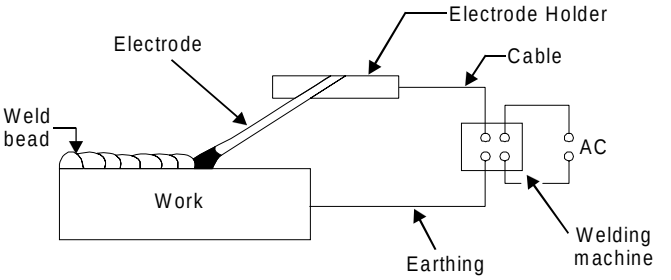
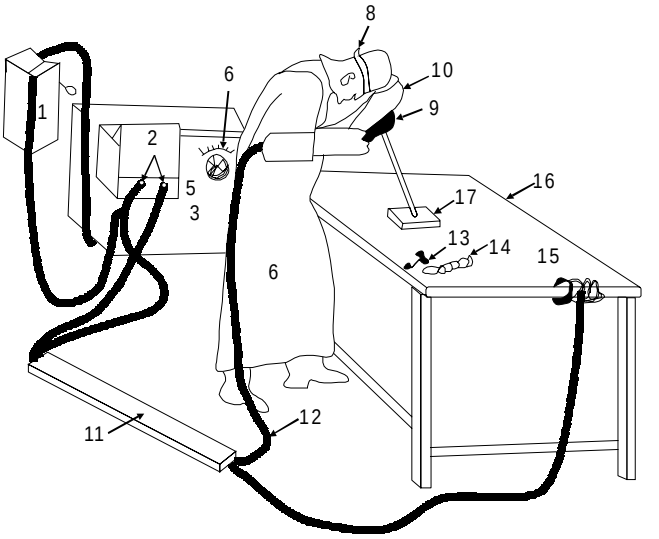


Fig. 17.9(a) Principle of arc welding



(1) Switch box.
(2) Secondary terminals.
(3) Welding machine.
(4) Current reading scale.
(5) Current regulating hand wheel.
(6) Leather apron.
(7) Asbestos hand gloves.
(8) Protective glasses strap.
(9) Electrode holder.
(10) Hand shield.
(11) Channel for cable protection.
(12) Welding cable.
(13) Chipping hammer.
(14) Wire brush.
(15) Earth clamp.
(16) Welding table (metallic).
(17) Job.

Fig. 17.9(b) Arc welding process setup

17.6.1 Arc Welding Equipment

Arc welding equipment, setup and related tools and accessories are shown in Fig. 17.9. However some common tools of arc welding are shown separately through Fig. 17.10-17.17. Few of the important components of arc welding setup are described as under.

1. Arc welding power source

Both direct current (DC) and alternating current (AC) are used for electric arc welding, each having its particular applications. DC welding supply is usually obtained from generators driven by electric motor or if no electricity is available by internal combustion engines. For AC welding supply, transformers are predominantly used for almost all arc welding where

mains electricity supply is available. They have to step down the usual supply voltage (200-400 volts) to the normal open circuit welding voltage (50-90 volts). The following factors influence the selection of a power source:

1. Type of electrodes to be used and metals to be welded
2. Available power source (AC or DC)
3. Required output
4. Duty cycle
5. Efficiency
6. Initial costs and running costs
7. Available floor space
8. Versatility of equipment

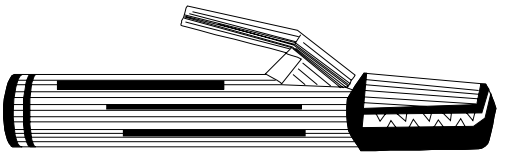


Fig. 17.10 Electrode holder

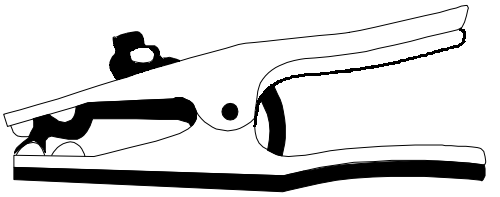


Fig. 17.11 Earth clamp

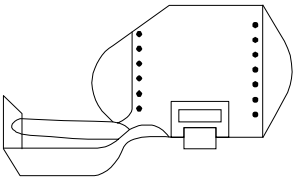


Fig. 17.12 Hand screen

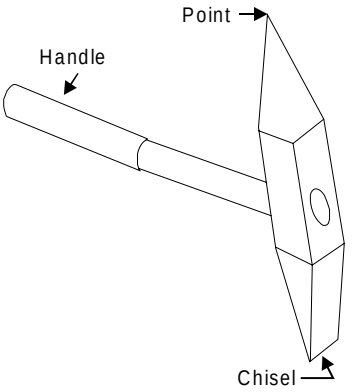


Fig. 17.13 Chipping and hammer

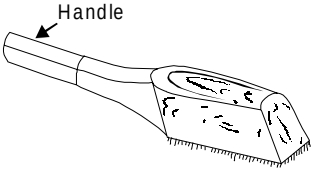


Fig. 17.14 Wire brush

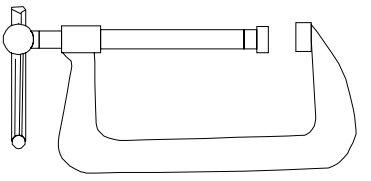


Fig. 17.15 C-clamp

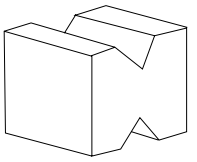


Fig. 17.16 V-block

Fig. 17.17 Scriber

2. Welding cables

Welding cables are required for conduction of current from the power source through the electrode holder, the arc, the workpiece and back to the welding power source. These are insulated copper or aluminium cables.

3. Electrode holder

Electrode holder is used for holding the electrode mannually and conducting current to it. These are usually matched to the size of the lead, which in turn matched to the amperage output of the arc welder. Electrode holders are available in sizes that range from 150 to 500 Amps.

4. Welding Electrodes

An electrode is a piece of wire or a rod of a metal or alloy, with or without coatings. An arc is set up between electrode and workpiece. Welding electrodes are classified into following types-

(1) Consumable Electrodes
   (*a*) Bare Electrodes
   (*b*) Coated Electrodes
(2) Non-consumable Electrodes
   (*a*) Carbon or Graphite Electrodes
   (*b*) Tungsten Electrodes

Consumable electrode is made of different metals and their alloys. The end of this electrode starts melting when arc is struck between the electrode and workpiece. Thus consumable electrode itself acts as a filler metal. Bare electrodes consist of a metal or alloy wire without any flux coating on them. Coated electrodes have flux coating which starts melting as soon as an electric arc is struck. This coating on melting performs many functions like prevention of joint from atmospheric contamination, arc stabilizers etc.

Non-consumable electrodes are made up of high melting point materials like carbon, pure tungsten or alloy tungsten etc. These electrodes do not melt away during welding. But practically, the electrode length goes on decreasing with the passage of time, because of oxidation and vaporization of the electrode material during welding. The materials of non-consumable electrodes are usually copper coated carbon or graphite, pure tungsten, thoriated or zirconiated tungsten.

5. Hand Screen

Hand screen (Fig. 17.12) used for protection of eyes and supervision of weld bead.

6. Chipping hammer

Chipping Hammer (Fig. 17.13) is used to remove the slag by striking.

7. Wire brush

Wire brush (Fi. 17.14) is used to clean the surface to be weld.

8. Protective clothing

Operator wears the protective clothing such as apron to keep away the exposure of direct heat to the body.

17.6.2 Carbon Arc Welding

In this process, a pure graphite or baked carbon rod is used as a non-consumable electrode to create an electric arc between it and the workpiece. The electric arc produces heat and weld can be made with or without the addition of filler material. Carbon arc welding may be classified as-

(1) Single electrode arc welding, and

(2) Twin carbon electrode arc welding

In single electrode arc welding, an electric arc is struck between a carbon electrode and the workpiece. Welding may be carried out in air or in an inert atmosphere. Direct current straight polarity (DCSP) is preferred to restrict electrode disintegration and the amount of carbon going into the weld metal. This process is mainly used for providing heat source for brazing, braze welding, soldering and heat treating as well as for repairing iron and steel castings. It is also used for welding of galvanized steel and copper.

In twin carbon arc welding the arc struck between two carbon electrodes produces heat and welds the joint. The arc produced between these two electrodes heats the metal to the melting temperature and welds the joint after solidification. The power source used is AC (Alternating Current) to keep the electrodes at the same temperature. Twin-electrode carbon arc welding can be used for welding in any position. This process is mainly used for joining copper alloys to each other or to ferrous metal. It can also be used for welding aluminium, nickel, zinc and lead alloys.

17.6.3 Shielded Metal Arc Welding (SMAW) or Manual Metal Arc Welding (MMAW)

Shielded metal arc welding (SMAW) is a commonly used arc welding process manually carried by welder. It is an arc welding process in which heat for welding is produced through an electric arc set up between a flux coated electrode and the workpiece. The flux coating of electrode decomposes due to arc heat and serves many functions, like weld metal protection, arc stability etc. Inner core of the electrode supply the filler material for making a weld. The basic setup of MMAW is depicted in Fig. 17.9 (a), (b) and the configuration of weld zone is shown in Fig. 17.18. If the parent metal is thick it may be necessary to make two or three passes for completing the weld. A typical multi pass bead in this case is shown in Fig. 17.19.

Advantages

1. Shielded Metal Arc Welding (SMAW) can be carried out in any position with highest weld quality.
2. MMAW is the simplest of all the arc welding processes.

3. This welding process finds innumerable applications, because of the availability of a wide variety of electrodes.
4. Big range of metals and their alloys can be welded easily.
5. The process can be very well employed for hard facing and metal resistance etc.
6. Joints (e.g., between nozzles and shell in a pressure vessel) which because of their position are difficult to be welded by automatic welding machines can be easily accomplished by flux shielded metal arc welding.
7. The MMAW welding equipment is portable and the cost is fairly low.

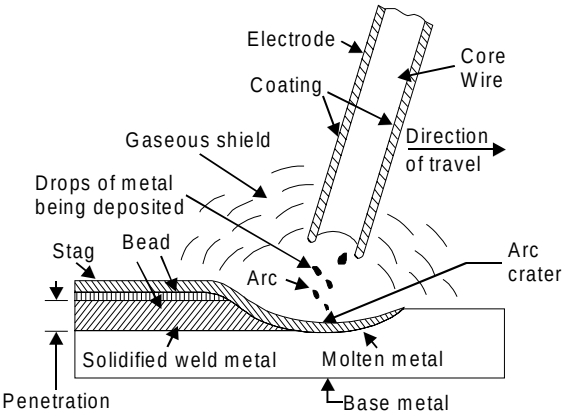


Fig. 17.18 Arc welding operation

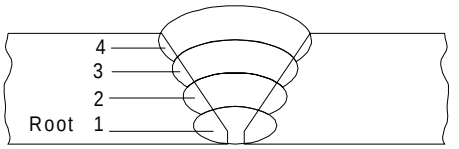


Fig. 17.19 A typical multi pass bead

Limitations

1. Due to flux coated electrodes, the chances of slag entrapment and other related defects are more as compared to MIG and TIG welding.
2. Duo to fumes and particles of slag, the arc and metal transfer is not very clear and thus welding control in this process is a bit difficult as compared to MIG welding.
3. Due to limited length of each electrode and brittle flux coating on it, mechanization is difficult.
4. In welding long joints (e.g., in pressure vessels), as one electrode finishes, the weld is to be progressed with the next electrode. Unless properly cared, a defect (like slag inclusion or insufficient penetration) may occur at the place where welding is restarted with the new electrode
5. The process uses stick electrodes and thus it is slower as compared to MIG welding.

Applications

1. Today, almost all the commonly employed metals and their alloys can be welded by this process.

2. Shielded metal arc welding is used both as a fabrication process and for maintenance and repair jobs.
3. The process finds applications in
   (*a*) Building and Bridge construction
   (*b*) Automotive and aircraft industry, etc.
   (*c*) Air receiver, tank, boiler and pressure vessel fabrication
   (*d*) Ship building
   (*e*) Pipes and
   (*f*) Penstock joining

17.6.3.1 Functions of Electrode Coating Ingredients

The covering coating on the core wire consists of many materials which perform a number of functions as listed below:

1. Welding electrodes are used to join various similar and dissimilar metals as plain carbon steels, cast iron, copper, aluminium, magnesium and their alloys, stainless steels and other alloy steels.
2. Slag forming ingredients, like silicates of magnesium, aluminium, sodium, potassium, iron oxide, china clay, mica etc., produce a slag which because of its light weight forms a layer on the molten metal and protects the same from atmospheric contamination.
3. Arc stabilizing constituents like calcium carbonate, potassium silicate, titanates, magnesium silicates, etc.; add to arc stability and ease of striking the same.
4. Gas shielding ingredients, like cellulose, wood, wood flour, starch, calcium carbonate etc. form a protective gas shield around the electrode end, arc and weld pool
5. Deoxidizing elements like ferro-manganese, and ferro-silicon, refine the molten metal.
6. It limits spatter, produces a quiet arc and easily removable slag.
7. Alloying elements like ferro alloys of manganese, molybdenum etc., may be added to impart suitable properties and strength to the weld metal and to make good the loss of some of the elements, which vaporize while welding.
8. Iron powder in the coating improves arc behavior, bead appearance helps increase metal deposition rate and arc travel speed.
9. The covering improves penetration and surface finish.
10. Core wire melts faster than the covering, thus forming a sleeve of the coating which constricts and produces an arc with high concentrated heat.
11. Coating saves the welder from the radiations otherwise emitted from a bare electrode while the current flows through it during welding.
12. Proper coating ingredients produce weld metals resistant to hot and cold cracking. Suitable coating will improve metal deposition rates.

17.6.4 Submerged Arc Welding

Schematic submerged arc welding process is shown in Fig. 17.20. In this welding process, a consumable bare electrode is used in combination with a flux feeder tube. The arc, end of the

bare electrode and molten pool remain completely submerged under blanket of granular flux. The feed of electrode and tube is automatic and the welding is homogenous in structure. No pressure is applied for welding purposes. This process is used for welding low carbon steel, bronze, nickel and other non-ferrous materials.

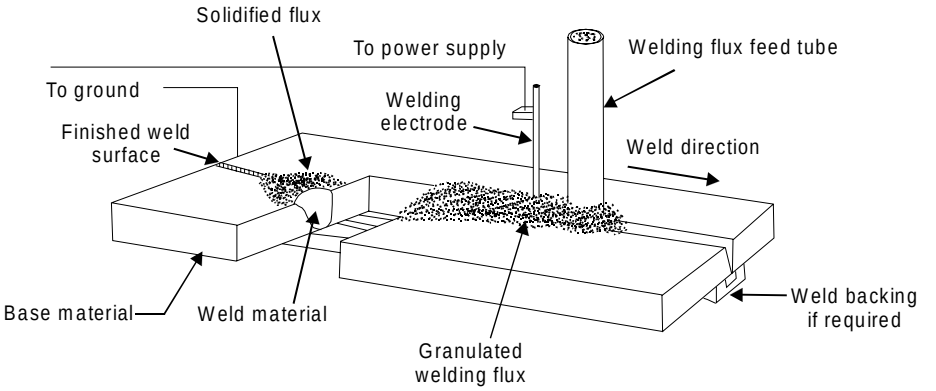


Fig. 17.20 Schematic submerged arc welding process

17.6.5 Gas Tungusten Arc Welding (GTAW) or Tungusten Inert Gas Welding (TIG)

In this process a non-consumable tungsten electrode is used with an envelope of inert shielding gas around it. The shielding gas protects the tungsten electrode and the molten metal weld pool from the atmospheric contamination. The shielding gases generally used are argon, helium or their mixtures. Typical tungsten inert gas welding setup is shown in Fig. 17.21.

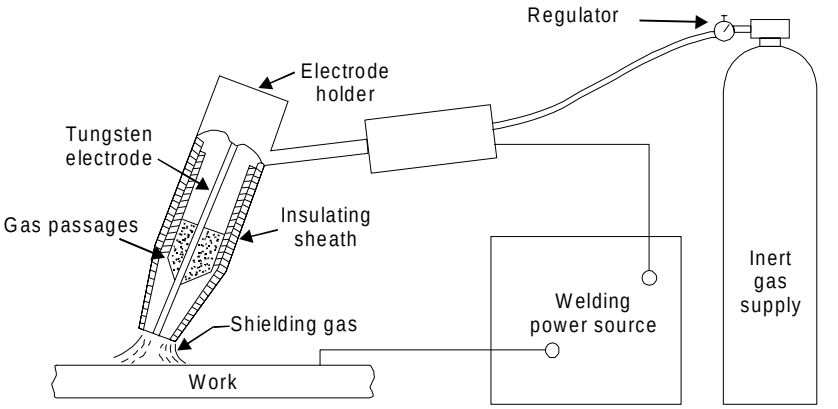


Fig. 17.21 Tungsten inert gas welding setup

Electrode materials

The electrode material may be tungsten, or tungsten alloy (thoriated tungsten or zirconiated tungsten). Alloy-tungsten electrodes possess higher current carrying capacity, produce a steadier arc as compared to pure tungsten electrodes and high resistance to contamination.

Electric power source

Both AC and DC power source can be used for TIG welding. DC is preferred for welding of copper, copper alloys, nickel and stainless steel whereas DC reverse polarity (DCRP) or AC is used for welding aluminium, magnesium or their alloys. DCRP removes oxide film on magnesium and aluminium.

Inert gases

The following inert gases are generally used in TIG welding:

1. Argon
2. Helium
3. Argon-helium mixtures
4. Argon-hydrogen mixtures

Tig Nozzle

The nozzle or shield size (the diameter of the opening of the shroud around the electrode) to be chosen depends on the shape of the groove to be welded as well as the required gas flow rate. The gas flow rate depends on the position of the weld as well as its size. Too high a gas consumption would give rise to turbulence of the weld metal pool and consequently porous welds. Because of the use of shielding gases, no fluxes are required to be used in inert gas shielded arc welding. However for thicker sections, it may be desirable to protect the root side of the joint by providing a flux. The process is generally used for welding aluminium, magnesium and stainless steel.

17.6.6 Gas Metal ARC Welding (GMAW) or Metal Inert Gas Welding (MIG)

Metal inert gas arc welding (MIG) or more appropriately called as gas metal arc welding (GMAW) utilizes a consumable electrode and hence, the term metal appears in the title. There are other gas shielded arc welding processes utilizing the consumable electrodes, such as flux cored arc welding (FCAW) all of which can be termed under MIG. Though gas tungsten arc welding (GTAW) can be used to weld all types of metals, it is more suitable for thin sheets. When thicker sheets are to be welded, the filler metal requirement makes GTAW difficult to use. In this situation, the GMAW comes handy. The typical setup for GMAW or MIG welding process is shown in Fig. 17.22. The consumable electrode is in the form of a wire reel which is fed at a constant rate, through the feed rollers. The welding torch is connected to the gas supply cylinder which provides the necessary inert gas. The electrode and the work-piece are connected to the welding power supply. The power supplies are always of the constant voltage type only. The current from the welding machine is changed by the rate of feeding of the electrode wire. Normally DC arc welding machines are used for GMAW with electrode positive (DCRP). The DCRP increases the metal deposition rate and also provides for a stable arc and smooth electrode metal transfer. With DCSP, the arc becomes highly unstable and also results in a large spatter. But special electrodes having calcium and titanium oxide mixtures as coatings are found to be good for welding steel with DCSP. In the GMAW process, the filler metal is transferred from the electrode to the joint. Depending on the current and voltage used for a given electrode, the metal transfer is done in different ways.

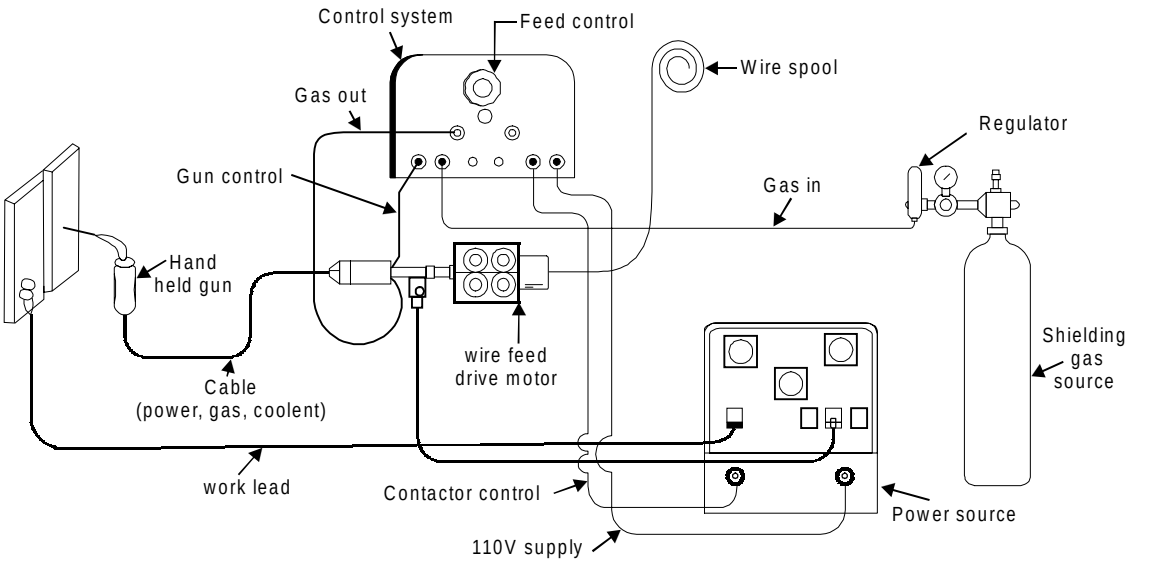


Fig. 17.22 Gas metal arc welding (GMAW) set up

17.6.7 Safety Recommendations for ARC Welding

The beginner in the field of arc welding must go through and become familiar with these general safety recommendations which are given as under.

1. The body or the frame of the welding machine shall be efficiently earthed. Pipe lines containing gases or inflammable liquids or conduits carrying electrical conductors shall not be used for a ground return circuit All earth connections shall be mechanically strong and electrically adequate for the required current.
2. Welding arc in addition to being very is a source of infra-red and ultra-violet light also; consequently the operator must use either helmet or a hand-shield fitted with a special filter glass to protect eyes
3. Excess ultra-violet light can cause an effect similar to sunburn on the skin of the welder
4. The welder's body and clothing are protected from radiation and burns caused by sparks and flying globules of molten metal with the help of the following:
5. Gloves protect the hands of a welder.
6. Leather or asbestos apron is very useful to protect welder's clothes and his trunk and thighs while seated he is doing welding.
7. For overhead welding, some form of protection for the head is required
8. Leather skull cap or peaked cap will do the needful.
9. Leather jackets and 1ather leggings are also available as clothes for body protection.
10. Welding equipment shall be inspected periodically and maintained in safe working order at all times.
11. Arc welding machines should be of suitable quality.
12. All parts of welding set shall be suitably enclosed and protected to meet the usual service conditions.

13. Welders and workers need to be protected from welding rays, f1ying sparks, metal globules and metal spatter, hot slag particles, hot stubs, fumes and gases when welding in confined spaces, e.g., rail tank wagon, falling when welding at a height from the ground.
14. In AC arc welding machines, in transformers, the secondary circuit shall be thoroughly insulated from the primary. Input terminal shall be completely enclosed and accessible only by means of tools.
15. The primary side of the transformer shall be provided with suitable wire terminals inside the machine case.
16. Welding (secondary) terminals shall be so arranged that current carrying parts are not exposed to accidental contact.
17. In a transformer, the welding circuit should be quite separate from power circuit, so that there is no risk of the welder suffering serious shock or burns through power voltage appearing across the electric holder.
18. At or near each welding machine, a disconnecting switch shall provide.
19. Control apparatus provided with the welding machine shall enclose except for the operating wheels, levers, etc.
20. Transformer windings be suction or compressed-air cleaned periodically.
21. Before undertaking any maintenance work on welding machine disconnects them from the main supply.
22. As regards other arc welding equipments, electrode holders should be soundly connected to the welding lead
23. They should be of adequate rating for the maximum welding current to prevent them from heating up and be coming too hot to handle.
24. Electrode holder sha1l be provided with discs or shields to protect the hands of the welder from heat of the arc. Installation of all metallic of current carrying parts, including the jaws which grip the electrodes, is recommended.
25. Hot electrode holders shall not be permitted to dip in water because the retained moisture may cause an electric shock.
26. Welding cables shall be of completely insulated, flexible type. They should be capable of handling the maximum current requirements of the work in progress, taking into account the duty cycle under which the welder is working in case the cable insulation is damaged, do not operate the equipment.
27. The welding cable should be free from repair or splices up to a minimum distance of three metres from the electrode holder.
28. Fully insulated cable connectors of capacity at least equivalent to that of the cable shall be used to connect two cables together.
29. Welding cables shall be kept dry and free from grease and oil to avoid premature breakdown of insulation.
30. Arc welding machines should be properly ground (earthed).
31. Construction of arc welding machines should be such that they can operate satisfactorily even under conditions of saltish or moist air as in coastal areas, dust,

smoke, fumes and gases, excessive shock or vibrations, steam and corrosive atmosphere, etc.

32. One should not work on the wiring of an arc welding machine unless qualified to do so.
33. Welding equipment used in the open and shall be protected from weather conditions. If it has been wetted it shall be thoroughly dried before being used.
34. Proper terminals should be used on the arc welding machines for the power line voltage connection.
35. Neither terminal of the welding generator shall be bonded to the frame of the welding machine.
36. Periodically clear out the accumulated dust from the welding machine with suction cleaner as this will not blow dust into other parts of the machine.
37. Over greasing may foul the commutators of DC generator.
38. Check and, if necessary, clean commutators of DC generator periodically, using fine sand paper.
39. Excessive sparking may result in a worn commutator of DC generator which may be cured by skimming in a lathe.
40. Brushes should move freely and have adequate spring tension. This can be tested by lifting and releasing them. Brushes should snap be firmly against the commutator of DC generator.
41. Greasing points need attention periodically.
42. Switch contacts should be cleaned periodically.

17.7 RESISTANCE WELDING

In resistance welding the metal parts to be joined are heated by their resistance to the flow of an electrical current. Usually this is the only source of heat, but a few of the welding operations combine resistance heating with arc heating, and possibly with combustion of metal in the arc. The process applies to practically all metals and most combinations of pure metals and those alloys, which have only a limited plastic range, are welded by heating the parts to fusion (melting). Some alloys, however, may welded without fusion; instead, the parts are heated to a plastic state at which the applied pressure causes their crystalline structures to grow together. The welding of dissimilar metals may be accomplished by melting both metals frequently only the metal with the lower melting point is melted, and an alloy bond is formed at the surface of the unmelted metal.

In resistance welding processes no fluxes are employed, the filler metal is rarely used and the joints are usually of the lap type. The amount of heat generated in the workpiece depend on the following factors:

(1) Magnitude of the current,

(2) Resistance of the current conducting path, and

Mathematically, $H = IVt$

$= I(IR)t$

$= I^2Rt$

Where H = heat generated in joules
I = current in Amp.
R = resistance in ohms
t = time of current flow in seconds.

17.7.1 Types of Resistance welding

The major types of resistance welding are given as under:

(1) Spot Welding
(2) Seam Welding
(3) Projection Welding
(4) Resistance Butt Welding
(5) Flash Butt Welding
(6) Percussion Welding
(7) High Frequency Resistance Welding
(8) High Frequency Induction Welding

Some of the above important welding processes are discussed as under,

17.7.1.1 Spot Welding

In this process overlapping sheets are joined by local fusion at one or more spots, by the concentration of current flowing between two electrodes. This is the most widely used resistance welding process. A typical resistance spot welding machine is shown in Fig. 17.23. It essentially consists of two electrodes, out of which one is fixed. The other electrode is fixed to a rocker arm (to provide mechanical advantage) for transmitting the mechanical force from a pneumatic cylinder. This is the simplest type of arrangement. The other possibility is that of a pneumatic or hydraulic cylinder being directly connected to the electrode without any rocker arm. For welding large assemblies such as car bodies, portable spot welding machines are used. Here the electrode holders and the pneumatic pressurizing system are present in the form of a portable assembly which is taken to the place, where the spot is to be made. The electric current, compressed air and the cooling water needed for the electrodes is supplied through cables and hoses from the main welding machine to the portable unit. In spot welding, a satisfactory weld is obtained when a proper current density is maintained. The current density depends on the contact area between the electrode and the work-piece. With the continuous use, if the tip becomes upset and- the contact area increases, the current density will be lowered and consequently the weld is obtained over a large area. This would not be able to melt the metal and hence there would be no proper fusion. A resistance welding schedule is the sequence of events that normally take place in each of the welds. The events are:

1. The squeeze time is the time required for the electrodes to align and clamp the two work-pieces together under them and provide the necessary electrical contact.
2. The weld time is the time of the current flow through the work-pieces till they are heated to the melting temperature.
3. The hold time is the time when the pressure is to be maintained on the molten metal without the electric current. During this time, the pieces are expected to be forged welded.

4. The off time is time during which, the pressure on the electrode is taken off so that the plates can be positioned for the next spot.

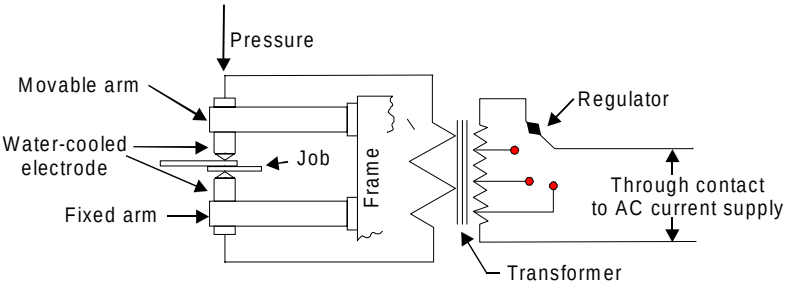


Fig. 17.23 Resistance spot welding machine setup

Before spot welding one must make sure that

(*i*) The job is clean, i.e., free from grease, dirt, paint, scale, oxide etc.

(*ii*) Electrode tip surface is clean, since it has to conduct the current into the work with as little loss as possible. Very fine emery cloth may be used for routine cleaning.

(*iii*) Water is running through the electrodes in order to

(*a*) Avoid them from getting overheated and thus damaged,

(*b*) Cool the weld.

(*iv*) Proper welding current has been set on the current selector switch.

(*v*) Proper time has been set on the weld-timer.

Spot welding electrodes

Spot welding electrodes are made of materials which have

(1) Higher electrical and thermal resistivities, and

(2) Sufficient strength to withstand high pressure at elevated temperatures.

Copper base alloys such as copper beryllium and copper tungsten are commonly used materials for spot welding electrodes. For achieving the desired current density, It is important to have proper electrode shape for which three main types of spot welding electrodes are used which are pointed, domed and flat electrodes.

Applications of Spot Welding

(*i*) It has applications in automobile and aircraft industries

(*ii*) The attachment of braces, brackets, pads or clips to formed sheet-metal parts such as cases, covers or trays is another application of spot welding.

(*iii*) Spot welding of two 12.5 mm thick steel plates has been done satisfactorily as a replacement for riveting.

(*iv*) Many assemblies of two or more sheet metal stampings that do not require gas tight or liquid tight joints can be more economically joined by spot welding than by mechanical methods.

(*v*) Containers and boxes frequently are spot welded.

17.7.1.2 Resistance Seam Welding

It is a continuous type of spot welding wherein spot welds overlap each other to the desired extent. In this process coalescence at the faying surfaces is produced by the heat obtained from the resistance to electric current (flow) through the work pieces held together under pressure by circular electrodes. The resulting weld is a series of overlapping resistance-spots welds made progressively along a joint by rotating the circular electrodes. The principle of seam welding is shown in Fig. 17.24(a) and resistance seam welding process set up is shown in Fig. 17.24(b). The seam welding is similar to spot welding, except that circular rolling electrodes are used to produce a continuous air-tight seam of overlapping welds. Overlapping continuous spot welds seams are produced by the rotating electrodes and a regularly interrupted current.

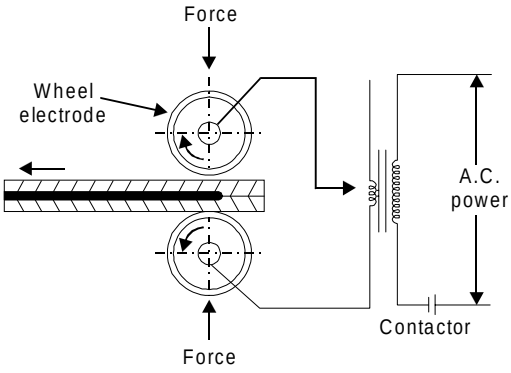


Fig. 17.24 (a) Principle of seam welding process

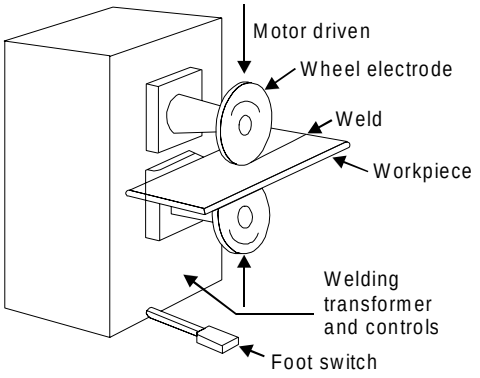


Fig. 17.24 (b) Resistance seam welding process setup

Applications

1. It is used for making leak proof joints in fuel tanks of automobiles.
2. Except for copper and high copper alloys, most other metals can be seam welded.
3. It is also used for making flange welds for use in watertight tanks.

17.7.1.3 Resistance Projection Welding

Fig.17.25 shows the projection welding. This process is a resistance welding process in which two or more than two spot welds are made simultaneously by making raised portions or projections on predetermined locations on one of the workpiece. These projections act to localize the heat of the welding circuit. The pieces to be welded are held in position under pressure being maintained by electrodes. The projected contact spot for welding should be approximately equal to the weld metal thickness. The welding of a nut on the automotive chasis is an example of projection welding.

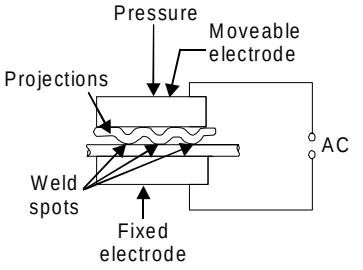


Fig. 17.25 Resistance projection welding

17.7.1.4 Resistance Upset Butt and Flash Butt Welding

This welding is also used for joining metal pieces end to end but it has largely replaced the butt-welding method for weld articles small cross-sections. It can be used for thick sections also. Initially the current is switched on and then one end the moveable part to be welded is brought gently closer to the fixed end of the other part to localize heat at the ends and thus raises the temperature of the ends quickly to the welding heat. On acquiring contact of fixed end and moveable end with each other, the moveable end is then pressed against one another by applying mechanical pressure. Thus the molten metal and slag to be squeezed out in the form of sparks enabling the pure metal to form the joint and disallowing the heat .to spread back. The principle of upset butt welding and flash butt welding are depicted in Fig. 17.26 (a, b). In this resistance welding single phase A.C. machines are commonly employed. The merits and demerit of flash welding over simple butt-welding are follows:

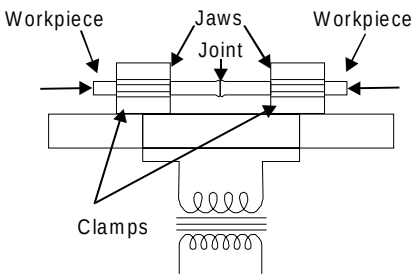


Fig. 17.26 (a) Resistance upset butt welding

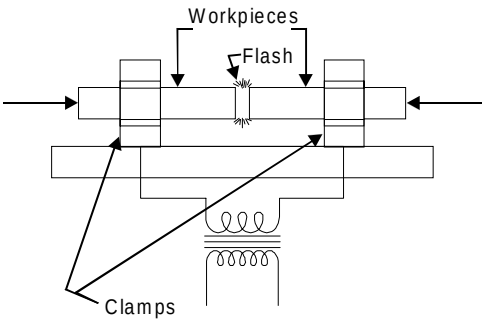


Fig. 17.26 (b) Resistance flash butt welding

Merits

1. It is comparatively much faster than butt welding.
2. This method utilizes less current in comparison to butt welding as the small portion of the metal is only being heated for getting a good weld
3. Created joint by this welding is much stronger than the butt welding joint. Also the strength of the weld produced is high even more than that of the base metal. The end of the metal pieces to be welded in this welding need not be squared as it is the basic requirement in butt-welding.
4. A high degree of accuracy can be easily achieved in terms of length alignment of weld.

Demerits

1. The periodic maintenance of machine and replacement of insulation is needed as flashing particles of molten metal are thrown out during welding which may enter into the slide ways and insulation of the set up.
2. Welder has to take enough care against possible fire hazard due to flashing during welding.
3. Additional stock has to be provided for compensating loss of metal during f1ashing and upsetting. This increases to the cost of weld.
4. Cost of removal of flash weld metal by trimming, chipping, grinding, etc. will increase to the welded product.

5. Surface of the jobs where they come in contact with the gripping surfaces, should be clean otherwise they will restrict the flow of electric current.
6. The available power, opening between the jaws of the gripping clamps and upsetting pressure of the welding set limit the size and cross sectional area of the jobs to be welded.

Applications

All conducting forged metals can be easily be flash welded. A number of dissimilar metals can also be welded by controlling the welding conditions carefully. Metals generally welded metal by the process involves lead, tin, antimony, zinc, bismuth and their alloys, low carbon steels, stainless steel, alloy steels, tool steels, copper alloys, aluminium alloys, magnesium alloys nickel alloys, molybdenum alloys, and titanium alloys. This process is used in automobile industry, welding of solid and tubular structural assemblies, etc. in air-craft industry, welding of band saw blades, welding of tool steel drills, reamers and taps etc. to mild steel or alloy steel shanks, welding of pipes and tubes.

17.7.2 Common Advantages of Resistance Welding

Some common advantages of resistance welding include:

(*a*) It is well suited for mass production.
(*b*) It is economical in operation, since nothing is consumed except electrical power.
(*c*) Skilled welders are not required.
(*d*) Welds are quickly made.
(*e*) It is possible to weld dissimilar metals.

Some disadvantages of resistance welding include:

(*a*) High initial cost of the resistance welding equipment
(*b*) Certain resistance welding processes are limited to lap joints.
(*c*) A lap joint has an inherent service between the two metal pieces, which causes stress concentrations in applications where fatigue is present. This service may also cause trouble when corrosion is present

17.8 SOLID STATE WELDING PROCESSES

In these processes, the base materials to be joined are heated to a temperature below or just upto the solidus temperature and then continuous pressure is applied to form the welded joint. No filler metal is used in solid-state welding processes. The various solid-state welding processes are-

(1) Forge Welding
(2) Cold Pressure Welding
(3) Friction Welding
(4) Explosive Welding
(5) Diffusion Welding
(6) Thermo-compression Welding

Some of the above important welding processes are discussed as under,

17.8.1 Forge Welding

In this welding process, the work-pieces to be welded are heated to the plastic condition (above 1000°C), and then placed together and forged while hot by applying force. Force may be applied by hammering, rolling, drawing or squeezing to achieve the forging action. Forge welding was originally the first process of welding. In this process the two metal pieces to be joined are heated in a forge or furnace to a plait condition and then they are united by pressure. The ends to be joined are heated in a furnace to plastic condition and formed to the required shape by upsetting. Then they are brought together and hammered, so as to get the finished joint similarly, a butt joint can be prepared by forge welding as shown in Fig. 17.3. Before joining the two pieces, their ends are formed to the required shape according to the type of joint. The forge welding is a manual process and is limited to light work because all forming and welding are done with a hand sledge. It is a slow process and there is considerable danger of an oxide scale forming on tile surfaces. The tendency to oxidize can be counteracted somewhat by using a thick fuel bed and by covering the surfaces with a fluxing material, which dissolves the oxides. Borax in combination with salt ammoniac is commonly used as flux. The forge welding is recommended to such metals, which have a large welding temperature range like low carbon steel and wrought iron. By the increase of carbon content, this range decreases rapidly. High carbon steels alloy steels require considerably more care in controlling temperature and producing the welds. Large work may be welded in hammer forges driven by steam. Welded steel pipe is made mechanically by running the preheated strips through rolls, which form the pipe to size and apply the necessary pressure for the weld.

17.8.2 Friction Welding

In this process, the heat for welding is obtained from mechanically induced sliding motion between rubbing surfaces of work-pieces as shown in Fig. 17.27. In friction welding, one part is firmly held while the other (usually cylindrical) is rotated under simultaneous application of axial pressure. As these parts are brought to rub against each other under pressure, they get heated due to friction. When the desired forging temperature is attained, the rotation is stopped and the axial pressure is increased to obtain forging action and hence welded joint. Most of the metals and their dissimilar combinations such as aluminium and titanium, copper and steel, aluminium and steel etc. can be welded using friction welding.

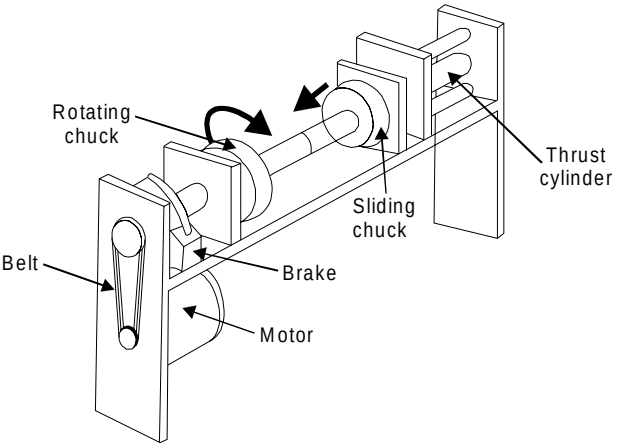


Fig. 17.27 Friction welding process

17.8.3 Explosive Welding

In explosive welding, strong metallurgical bonds can be produced between metal combinations which cannot be welded by other methods or processes. For example, tantalum can be explosively welded to steel although the welding point of tantalum is higher than the vaporization temperature of steel. Explosive welding process is shown in Fig. 17.28. It is carried out by bringing together properly paired metal surfaces with high relative velocity at a high pressure and a proper orientation to each other so that a large amount of plastic interaction occurs between the surfaces. The work piece, held fixed is called the target plate and the other called flyer plate. While a variety of procedures have been successfully employed, the main techniques of explosive welding can be divided into contact techniques and impact techniques. In critical space and nuclear application, explosive welding permits fabrication of structures that cannot be made by any other means and, in some commercial applications, explosive joining is the least costly method. The main advantage of explosive welding includes the simplicity of the process, and the extremely large surface that can be welded. Incompatible materials can also be bonded, and thin foils can be bonded to heavier plates.

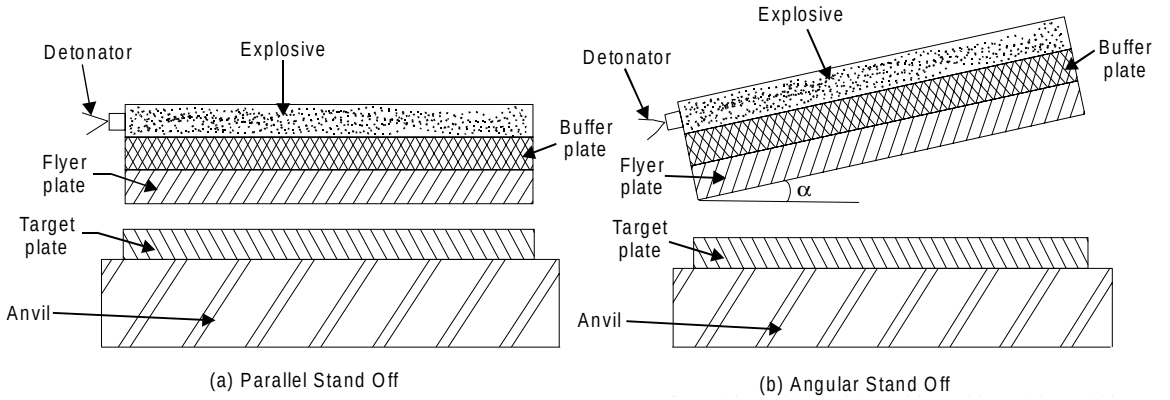


Fig. 17.28 Explosive welding process

17.9 THERMIT WELDING

It may be of forge or fusion kind of welding. Fusion welding requires no pressure. Thermit welding process is depicted in Fig. 17.29. It is a process which uses a mixture of iron oxide and granular aluminium. This mixture in superheat liquid state is poured around the parts to be joined. The joint is equipped with the refractory mold structure all around. In case of thermit pressure welding, only the heat of thermit reaction is utilized to bring the surface of metal to be welded in plastic state and pressure is the applied to complete the weld. The temperature produced in the thermit reaction is of the order of 3000°C. Thermit welding is used for welding pipes, cables, conductors, shafts, and broken machinery frames, rails and repair of large gear tooth.

17.10 RADIANT ENERGY WELDING PROCESSES

In radiant energy welding processes, heat is produced at the point of welding when a stream of electrons or a beam of electro-magnetic radiations strikes on the workpiece. This welding can be carried out in vacuum or at low pressures. Electron beam welding (EBW) and laser welding are two main types of radiant energy welding processes.

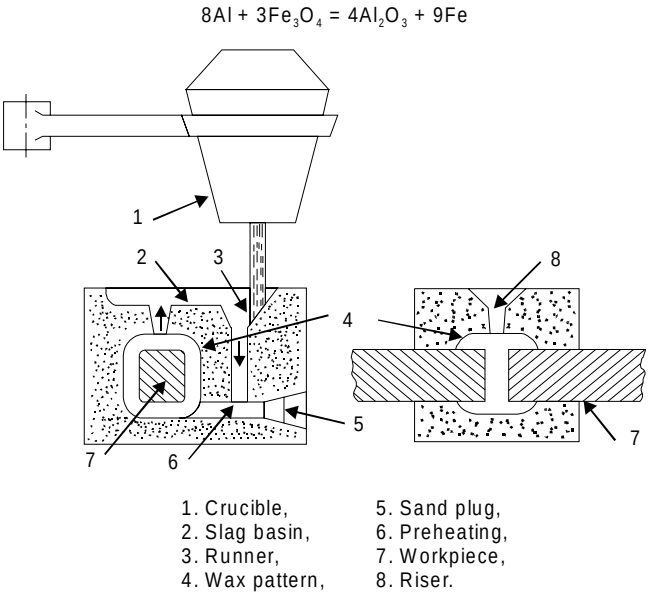


Fig. 17.29 Thermit welding process

17.10.1 Electron Beam Weldinig (EBW)

In EBW process, the heat is generated when the electron beam impinges on work piece. As the high velocity electron beam strikes the surfaces to be welded, their kinetic energy changes to thermal energy and hence causes the workpiece metal to melt and fuse.

A schematic setup of the electron beam welding is shown in Fig. 17.30. This process employs an electron gun in which the cathode in form of hot filament of tungsten or tantalum is the source of a stream of electrons. The electrons emitted from filament by thermionic emission are accelerated to a high velocity to the anode because of the large potential difference that exists between them. The potential differences that are used are of the order of 30 kV to 175 kV. The higher the potential difference, higher would be the acceleration. The current levels are low ranging between 50 mA to 1000 mA. The electron beam is focused by a magnetic lens system on the workpieces to be welded. The depth of penetration of the weld depends on the electron speed which in turn is dependent upon the accelerating voltage. When the high velocity electron beam strikes the work-piece all the kinetic energy is converted to heat. As these electrons penetrate the metal, the material that is directly in the path is melted which when solidifies form the joint. Electron beam welding has several advantages which may not be found in other welding processes. The penetration of the beam is high. The depth to width ratios lies between 10:1 to 30:1 can be easily realized with electron beam welding. It is also possible to closely control this penetration by controlling the accelerating voltage, beam current, and beam focus. The process can be used at higher welding speeds typically between 125 and 200 mm/sec. No filler metal or flux needs to be used in this process. The heat liberated is low and also is in a narrow zone, thus the heat affected zone is minimal as well as weld distortions are virtually eliminated. It is possible to carry out the electron beam welding in open atmosphere. For welding in vacuum, the work-piece is enclosed in a box in which the vacuum is created. When electron beam moves in the normal atmosphere, the electrons would be impinging with the gas molecules in the atmosphere and would thus

be scattered. This scattering increases the spot size of the electron beam and consequently there is lower penetration. As the vacuum increases, the scattering effect of the electron beam decreases and hence, penetration increases. The other advantage of using vacuum is that the weld metal is not contaminated.

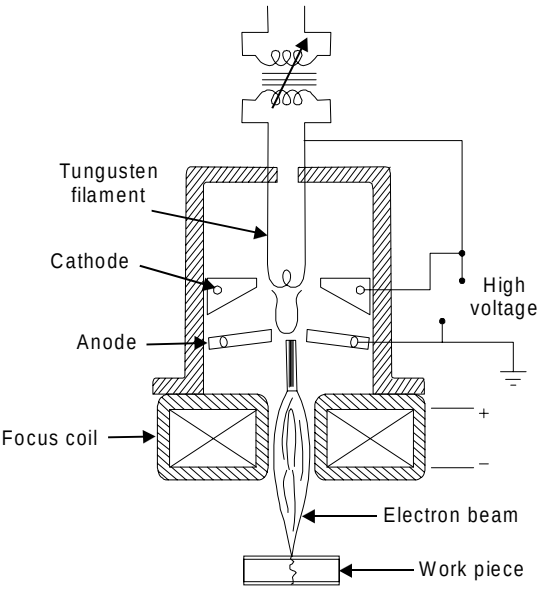


Fig. 17.30 Electron beam welding set up

The EBW process is mainly used for welding of reactive metals (nuclear reactor components), titanium, zirconium, stainless steel, etc. for aero-space and automotive industries.

17.11 EFFECTS OF WELDING HEAT

During the process of welding, the metal is heated over a range of temperature up to fusion and then allowed to cool. Heating and cooling causes metallurgical and mechanical effects on the metal pieces being welded. The region of the base metal which is affected by metallurgical change due to the welding heat is called the heat affected zone. In this zone, the metal has been heated and cooled through a range of temperature great enough to cause changes in the structure of the metal. The amount of change may be controlled by using the suitable welding processes. Sometimes, the original properties may be restored by heat treatment after welding. Although the mechanical strength of weld metals is at least equal to that of the base metal but the metallurgical changes can reduce greatly the associated properties of the joint particularly for shock and fatigue.

Mechanical effects of welding heat are the distortion and the residual stress resulting from welding. The magnitude of these effects depends on the factors of design and welding procedure. But the effects will always be present to a certain extent in any structure fabricated or repaired by non-pressure welding. Because of expansion and contraction of the heated portion the distortion and residual stresses set up. The base metal heated locally will expand and up set owing to the restraint imposed by tile surrounding cold metal. This upset portion of the base metal will contract on cooling beyond its original dimensions and thereby setup internal stresses causing distortion. If the pieces being welded are not tree to move, high residual stresses will be formed which may cause cracking during welding.

The residual stresses also reduce load carrying capacity of the structure. The residual stresses may be relieved by heat treatment. Preheating the whole structure is helpful to reduce residual stresses. Certain procedures and proper welding sequences are also used in removing the distortion and internal stress. It is to be noted that the flow of heat in the weld zone is highly directional towards the adjacent cold metal, which produces columnar grains at right angle to the fusion line. The columnar structure is a characteristic of the metal of single pass welds. Thus the original structure consisting of ferrite and pearlite in slabs is changed to another microstructure. The composition of the first crystal which form a molten alloy may quite different from the composition of the liquid, but as the freezing proceeds, the crystals readjust their composition to that of the initial liquid alloy in order to satisfy the condition of equilibrium. The weld metal when it is in the molten state can dissolve in ore gases, which come into contact with it, like oxygen, nitrogen and hydrogen. But as the metal cools it looses its dissolving capacity and the dissolved gases become free from the metal creating gas pockets and porosity in the final weld.

Welding processes widely used in the industry include oxy-acetylene, manual metal arc or shielded metal arc, submerged arc, gas metal arc, gas tungsten arc welding, resistance welding, thermit welding and cold pressure welding. Most of these processes have special fields of influence like resistance welding is popular with the automobile industry, thermit welding for joining rails. Gas metal arc welding is particularly suited for welding of low carbon steel structures as also welding of stainless steels and aluminium. It is more popular in aeronautical and nuclear industries. Submerged arc welding is used for ship building. Cold pressure welding is preferred by food processing industry. However, Arc welding and oxy-acetylene welding, processes are the general purpose processes with a wide range of applications. Some of the typical applications of welding include the fabrication of ships, pressure vessels, automobile bodies, off-shore platform, bridges, welded pipes, sealing of nuclear fuel and explosives, etc. The knowledge of welding is much essential to make welded fabrications a success.

17.12 WELDING DEFECTS

Defects in welding joints are given in 17.31 (*i-viii*)

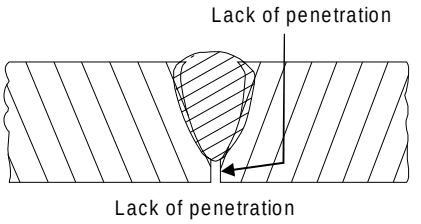


Fig. 17.31(i)

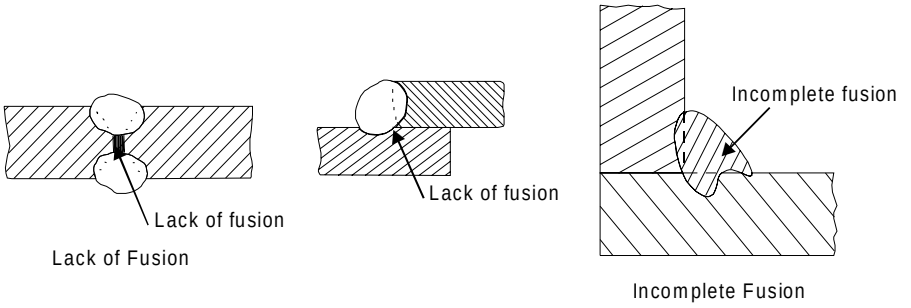
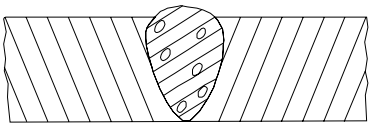
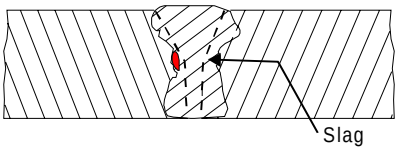


Fig. 17.31(ii)



Porosity

Fig. 17.31(iii)



Slag Inclusion

Fig. 17.31(iv)

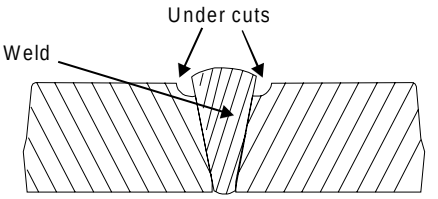
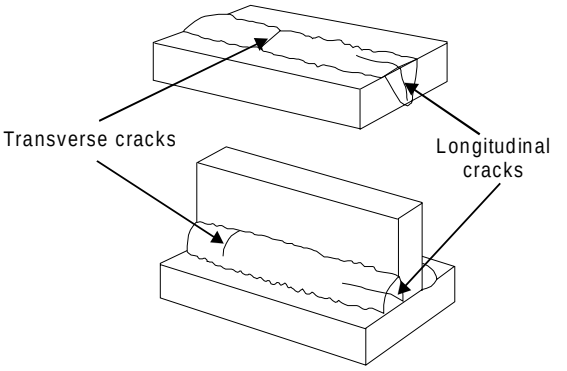
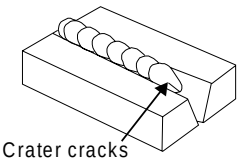


Fig. 17.31(v)

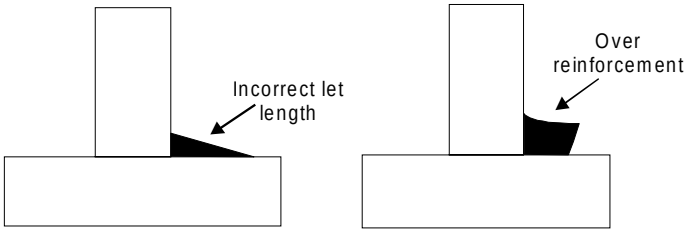


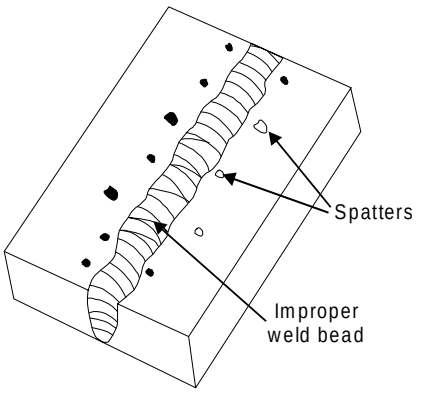
(a) Longitudinal and Transverse Crack



(b) Crater cracks

Fig. 17.31(vi)





Poor Weld Bead Appearance

Fig. 17.31(vii)

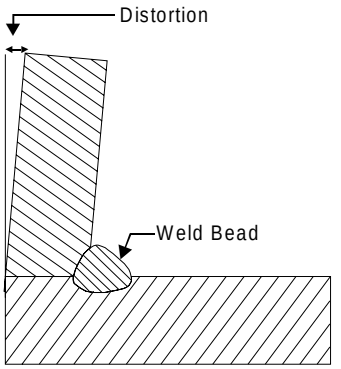


Fig. 17.31(viii)

Fig. 17.31 Types of welding defects

1. Lack of Penetration (Fig. 17.31 (i))

It is the failure of the filler metal to penetrate into the joint. It is due to

(*a*) Inadequate de-slagging
(*b*) Incorrect edge penetration
(*c*) Incorrect welding technique.

2. Lack of Fusion (Fig. 17.31 (ii))

Lack of fusion is the failure of the filler metal to fuse with the parent metal. It is duo to

(*a*) Too fast a travel
(*b*) Incorrect welding technique
(*c*) Insufficient heat

3. Porosity (Fig. 17.31 (iii))

It is a group of small holes throughout the weld metal. It is caused by the trapping of gas during the welding process, due to

(*a*) Chemicals in the metal
(*b*) Dampness
(*c*) Too rapid cooling of the weld.

4. Slag Inclusion (Fig. 17.31 (iv))

It is the entrapment of slag or other impurities in the weld. It is caused by

(*a*) Slag from previous runs not being cleaned away,
(*b*) Insufficient cleaning and preparation of the base metal before welding commences.

5. Undercuts (Fig. 17.31 (v))

These are grooves or slots along the edges of the weld caused by

(*a*) Too fast a travel

(*b*) Bad welding technique

(*c*) Too great a heat build-up.

6. Cracking (Fig. 17.31 (vi))

It is the formation of cracks either in the weld metal or in the parent metal. It is due to

(*a*) Unsuitable parent metals used in the weld

(*b*) Bad welding technique.

7. Poor Weld Bead Appearance (Fig. 17.31 (vii))

If the width of weld bead deposited is not uniform or straight, then the weld bead is termed as poor. It is due to improper arc length, improper welding technique, damaged electrode coating and poor electrode and earthing connections. It can be reduced by taking into considerations the above factors.

8. Distortion (Fig. 17.31 (viii))

Distortion is due to high cooling rate, small diameter electrode, poor clamping and slow arc travel speed

9. Overlays

These consist of metal that has flowed on to the parent metal without fusing with it. The defect is due to

(*a*) Contamination of the surface of the parent metal

(*b*) Insufficient heat

10. Blowholes

These are large holes in the weld caused by

(*a*) Gas being trapped, due to moisture.

(*b*) Contamination of either the filler or parent metals.

11. Burn Through

It is the collapse of the weld pool due to

(*a*) Too great a heat concentration

(*b*) Poor edge preparation.

12. Excessive Penetration

It is where the weld metal protrudes through the root of the weld. It is caused by

(*a*) Incorrect edge preparation

(*b*) Too big a heat concentration

(*c*) Too slow a travel.

17.13 BRAZING

Like soldering, brazing is a process of joining metals without melting the base metal. Filler material used for brazing has liquidus temperature above 450°C and below the solidus

temperature of the base metal. The filler metal is drawn into the joint by means of capillary action (entering of fluid into tightly fitted surfaces). Brazing is a much widely used joining process in various industries because of its many advantages. Due to the higher melting point of the filler material, the joint strength is more than in soldering. Almost all metals can be joined by brazing except aluminum and magnesium which cannot easily be joined by brazing. Dissimilar metals, such as stainless steel to cast iron can be joined by brazing. Because of the lower temperatures used there is less distortion in brazed joints. Also, in many cases the original heat treatment of the plates being joined is not affected by the brazing heat. The joint can be quickly finished without much skill. Because of the simplicity of the process it is often an economical joining method with reasonable joint strength. The brazed joints are reasonably stronger, depending on the strength of the filler metal used. But the brazed joint is generally not useful for high temperature service because of the low melting temperature of the filler metal. The color of the filler metal in the brazed joint also, may not match with that of the base metal. Because the filler metal reaches the joint by capillary action, it is essential that the joint is designed properly. The clearance between the two parts to be joined should be critically controlled. Another important factor to be considered is the temperature at which the filler metal is entering the joint.

During brazing, the base metal of the two pieces to be joined is not melted. An important requirement is that the filler metal must wet the base metal surfaces to which it is applied. The diffusion or alloying of the filler metal with the base metal place even though the base metal does not reach its solidus temperature. The surfaces to be joined must be chemically clean before brazing. However, fluxes are applied to remove oxides from the surfaces. Borax is the most widely used flux during the process of brazing. It will dissolve the oxides of most of the common metals.

17.13.1 Methods of Brazing

Torch Brazing

It is the most widely used brazing method. Heat is produced, generally, by burning a mixture of oxy-acetylene gas, as in the gas welding. A carbonizing flame is suitable for this purpose as it produces sufficiently high temperature needed for brazing.

Furnace Brazing

It is suitable for brazing large number of small or medium parts. Usually brazing filler metal in the granular or powder form or as strips is placed at the joint, and then the assembly is placed in the furnace and heated. Large number of small parts can be accommodated in a furnace and simultaneously brazed.

17.13.2 Braze Welding

In welding processes where the joint of the base metal is melted and a joint is prepared having higher joint strength, it is likely to cause metallurgical damage by way of phase transformations and oxide formation. In this process, the base metal is not melted, but the joint is obtained by means of a filler metal.

17.14 SOLDERING

Soldering is a method of joining similar or dissimilar metals by heating them to a suitable temperature and by means of a filler metal, called solder, having liquidus temperuatre not

exceeding 450°C and below the solidus of the base material. Though soldering obtains a good joint between the two plates, the strength of the joint is limited by the strength of the filler metal used.

Solders are essentially alloys of lead and tin. To improve the mechanical properties and temperature resistance, solders are added to other alloying elements such as zinc, cadmium and silver in various proportions. Soldering is normally used for obtaining a neat leak proof joint or a low resistance electrical joint. The soldered joints are not suitable for high temperature service because of the low melting temperatures of the filler metals used. The soldering joints also need to be cleaned meticulously to provide chemically clean surfaces to obtain a proper bond. Solvent cleaning, acid pickling and even mechanical cleaning are applied before soldering. To remove the oxides from the joint surfaces and to prevent the filler metal from oxidizing, fluxes are generally used in soldering. Rosin and rosin plus alcohol based fluxes are least active type and are generally used for electrical soldering work. Because of the content of acids, these are corrosive at soldering temperature. They can be easily cleaned after the soldering. The organic fluxes such as zinc chloride and ammonium chloride are quick acting and produce efficient joints. But because of their corrosive nature the joint should be thoroughly cleaned of the entire flux residue from the joint. These are to be used for only non-electrical soldering work. Fluxes are normally available in the form of powder, paste, liquid or in the form of core in the solder metal. It is necessary that the flux should remain in the liquid form at the soldering temperature and be reactive to be of proper use.

The most commonly used soldering methods include soldering iron (flame or electrically heated), dip soldering, and wave soldering. A soldering iron is a copper rod with a thin tip which can be used for flattening the soldering material. The soldering iron can be heated by keeping in a furnace or by means of an internal electrical resistance whose power rating may range from 15 W for the electronic applications to 200 W for sheet metal joining. This is the most convenient method of soldering but somewhat slower compared to the other methods. In dip soldering, a large amount of solder is melted in a tank which is closed. The parts that are to be soldered are first cleaned properly and dipped in a flux bath as per the requirement. These are then dipped into the molten solder pool and lifted with the soldering complete. The wave soldering is a variant of this method wherein the part to be soldered (e.g." an electronic printed circuit board, PCB) is not dipped into the solder tank, but a wave is generated in the tank so that the solder comes up and makes a necessary joint.

17.14.1 Basic Operations in Soldering

For making soldered joints, following operations are required to be performed sequentially.

1. Shaping and fitting of metal parts together

Filler metal on heating flows between the closely placed adjacent surfaces due to capillary action, thus, closer the parts the more is solder penetration. This means that the two parts should be shaped to fit closely so that the space between them is extremely small to be filled completely with solder by the capillary action. If a large gap is present, capillary action will not take place and the joint will not be strong.

2. Cleaning of surfaces

This is done to remove dirt, grease or any other foreign material from the surface pieces to be soldered, in order to get a sound joint. If surfaces are not clean, strong atomic bonds will not form.

3. Flux application

Soldering cannot be done without a flux. Even if a metal is clean, it rapidly acquires an oxide film of submicroscopic thickness due to heat and this film insulates the metal from the solder, preventing the surface to get wetted by solder. This film is broken and removed by the flux. The flux is applied when parts are ready for joining.

4. Application of heat and solder

The parts must be held in a vice or with special work holding devices so that they do not move while soldering. The parts being soldered must be heated to solder-melting and solder-alloying temperature before applying the solder for soldering to take place the assembly so that the heat is most effectively transmitted to the being soldered.

As soon as the heat is applied, the flux quickly breaks down the oxide film (the insulating oxide layer barrier between the surface and solder). Now solder is applied which immediately melts and metal to metal contact is established through the medium of molten solder. Finally, the surplus solder is removed and the joint is allowed to cool. Blow torches dipping the parts in molten solder or other methods are also used for soldering.

17.14.2 Solders

Solders are alloys of lead and tin. Solder may also contain certain other elements like cadmium, and antimony in small quantities. The percentage composition of tin and lead determines the physical and mechanical properties of the solder and the joint made. Most solder is available in many forms-bar, stick, fill, wire, strip, and so on. It can be obtained in circular or semi-circular rings or any other desired shape. Sometimes the flux is included with the solder. For example, a cored solder wire is a tube of solder filled with flux.

17.14.3 Solder Fluxes

The flux does not constitute a part of the soldered joint. Zinc chloride, ammonium chloride, and hydrochloric acid are the examples of fluxes commonly used in soldering. The function of fluxes in soldering is to remove oxides and other surface compounds from the surfaces to be soldered by displacing or dissolving them. Soldering fluxes may be classified into four groups-

(1) Inorganic fluxes (most active)
(2) Organic fluxes (moderately active)
(3) Rosin fluxes (least active), and
(4) Special fluxes for specific applications

17.15 QUESTIONS

1. What is welding? How is it classified?
2. What are the advantages, disadvantages and applications of welding joints over other joints?
3. Explain the various types of joints commonly used in welding.
4. Explain the different kinds of welding positions with neat sketch.
5. Using neat sketch show the various standard location of elements of a welding symbol.
6. Classify the various welding processes in detail. Describe each in brief.

7. What effect does welding have on the grain-size of a metal? What effect will pre-heating have on the microstructure of the weld-area in high carbon steel? Show it with the help of neat diagram.
8. Sketch a gas welding set-up.
9. How is gas welding performed? How is the flame adjusted?
10. Sketch the three types of gas welding flames and give differences between them.
11. Give the advantages, limitations and applications of gas welding?
12. Describe gas welding techniques in detail?
13. Write short notes on :
    (*i*) Welding rods
    (*ii*) Fluxes
    (*iii*) Gas flames
    (*iv*) Working of pressure regulators
    (*v*) Working pressure of gases in H.P and L.P welding and cutting.
14. What procedure and care will you follow in operating?
    (*i*) A low pressure plant
    (*ii*) A high pressure plant.
15. How will you obtain neutral, oxidizing and reducing flames using welding torch in gas welding?
16. What are the main requirements of a good flux used in gas welding?
17. What is a gas welding rod?
18. Give the complete procedure of gas welding.
19. Compare high pressure and low pressure gas welding
20. Sketch an oxygen cylinder. How does it differ from acetylene cylinder?
21. How will you generate and store acetylene gas?
22. Sketch a single stage pressure reduction regulator and explain its working.
23. Write short notes on the following:
    (*i*) Hoses
    (*ii*) Torch tip
    (*iii*) Welding torch and its parts
    (*iv*) Welding goggles
    (*v*) Wire brush
    (*vi*) Filler rod in gas welding
24. Describe the method of oxy-acetylene cutting.
25. Define electric arc welding. Discuss with the help of neat sketch, the principle of arc welding. What is straight polarity and reverse polarity?
26. Give a list of equipments required in general for electric arc welding.
27. Explain the principle of arc-welding.
28. What do you understand by the term polarity?
29. What is the advantage of having different polarities?
30. Compare the merits and demerits of using A.C and D.C for arc welding.

31. Describe briefly the methods of carbon arc and metallic arc welding.
32. Compare A.C. power source welding with D.C. power source welding.
33. Explain the principle of atomic hydrogen welding.
34. Write short notes on :
    (*a*) Arc crater
    (*b*) Arc blow
    (*c*) Electrode
    (*d*) Flux
35. What safety precautions are associated with electric arc welding?
36. Explain carbon arc welding with neat sketch.
37. Explain TIG welding and MIG welding with its merits, demerits and application.
38. Compare TIG welding with MIG welding.
39. Explain submerged arc welding with neat sketch.
40. Explain electro-slag welding with neat sketch. Compare it with electro-gas welding.
41. Define flux shielded metal arc welding.
42. Explain operation, equipment, advantages, disadvantages and applications of flux shielded metal arc welding.
43. Explain plasma arc welding with neat sketch.
44. Compare plasma arc welding and TIG welding.
45. What do you under stand by thermit welding? What are its main advantages?
46. How does thermit welding process differ from ordinary arc welding?
47. Write short notes on:
    (*i*) Forge or smithy welding.
    (*ii*) Leftward welding.
    (*iii*) Rightward welding.
    (*iv*) Vertical welding
48. What are the electrodes used in arc welding made of? What is electrode coating and why are they provided?
49. How is an electrode specified? What factors govern the selection of an electrode?
50. Describe the following welding methods and their specific merits, demerits and applications:
    (*i*) TIG welding
    (*ii*) MIG welding
51. Describe the process of submerged arc welding stating its advantages and limitations.
52. With the help of a neat diagram explain the process of electro slag welding.
53. Discuss the method of resistance welding. What are its advantages and disadvantages?
54. What is the main source of heat in resistance welding? Why is the control of pressure important in resistance welding?
55. Compare spot welding with seam welding.
56. Discuss, with the help of neat sketch, the principle of spot welding,
57. Describe in detail with set up process parameters, advantages, disadvantages and applications of the following:

(*i*) Spot welding
(*ii*) Seam welding
(*iii*) Projection welding
(*iv*) Upset butt welding
(*v*) Flash butt welding
(*vi*) Percussion welding

58. Write short notes on following:
(*i*) Soldering
(*ii*) Brazing
(*iii*) Braze welding
59. Differentiate between soldering, brazing and welding.
60. Write short notes on:
(*i*) Electro-gas welding.
(*ii*) Stud welding.
(*iii*) Plasma arc welding.

18
CHAPTER

SHEET METAL WORK

18.1 INTRODUCTION

Products made through the sheet metal processing include automobile bodies, utensils, almirah, cabinet's appliances, electronic components, electrical parts, aerospace parts, refrigeration and air conditioning parts etc. Sheet metal is generally considered to be a plate with thickness less than about 5 mm. Articles made by sheet metal work are less expensive and lighter in weight. Sheet metal forming work started long back 5000 BC. As compared to casting and forging, sheet-metal parts offer advantages of lightweight and versatile shapes. Because of the good strength and formability characteristics, low carbon steel is the most commonly utilized in sheet-metal processing work. The metal stampings have now replaced many components, which were earlier made by casting or machining. In few cases sheet metal products are used for replacing the use of castings or forgings. Sheet metal work has its own significance in the engineering work. Sheet metal processing has its own significance as a useful trade in engineering works to meet our day-to-day requirements. Many products, which fulfill the household needs, decoration work and various engineering articles, are produced from sheet meta1s. A good product properly developed may lead to saving of time and money.

In sheet-metal working, there is no need for further machining as required for casting and forging works. The time taken in sheet-metal working is approximately half of that required in the machining process. For carrying out sheet metal work, the knowledge of geometry, mensuration and properties of metal is most essential because nearly all patterns come from the development of the surfaces of a number of geometrical models such as cylinder, prism, cone, and pyramid. In sheet metal work, various operations such as shearing, blanking, piercing, trimming, shaving, notching, forming, bending, stamping, coining, embossing etc. are to be performed on sheet metal using hand tools and press machines to make a product of desired shape and size. Generally metals used in sheet metal work are black iron, galvanized iron, stainless steel, copper, brass, zinc, aluminium, tin plate and lead.

18.2 METALS USED IN SHEET METAL WORK

The following metals are generally used in sheet metal work:

1. Black Iron Sheet

It is probably the cheapest of all the metal used for sheet metal work. It is bluish black in appearance and is used generally in form of uncoated sheet. It can be easily rolled into the desired thickness. Since it is uncoated it corrodes rapidly. Hence to increase its life it can be painted or enameled. This metal is generally used in the making or roofs, food containers, stove pipes, furnace fittings, dairy equipments, tanks, cans and pans, etc.

2. Galvanized Iron (G.I.)

It is popularly known as G.I. sheets. It is soft steel coated with molten zinc. This coating resists rust formation on surface and improves appearance and water resistance. Articles such as pans, furnaces, buckets, cabinets etc. are made from GI sheets.

3. Stainless Steel

It is an alloy of steel with nickel, chromium and small percentages of other metals. It has good corrosion resistance. It is costlier but tougher than GI sheets. 1t is used in kitchenware, food processing equipments, food handling articles, tools and instruments for surgery work in hospitals and components of chemical plants etc.

Other metal sheets used for sheet metal work are made up of copper, aluminum, tin, and lead.

18.3 SHEET METAL TOOLS

The following tools are commonly used for sheet-metal work:

(*i*) Hand shears or snips
(*ii*) Hammers
(*iii*) Stakes and stake holder
(*iv*) Cutting tools
(*v*) Measuring tools
(*vi*) Miscellaneous hand tools such as chisels, groovers, seamers, rivet sets and hand punches.

Some of the important sheet metal tools are described as under.

18.3.1 HAND SHEARS OR SNIPS

Fig 18.1 shows the types of hand shears or snips. They resemble with pair of scissors and are used like them to cut thin soft metal sheets of 20 gauge or thinner. They are required to size and shape the sheets. They can make straight or circular cuts. Different types of hand shears are:

(1) **Straight hand shear:** It is used for general purpose cutting, making straight cuts and trimming away extra metal.
(2) **Universal shear:** Its blades are designed for universal cutting straight line or internal and external cutting of contours. It may be of right hand or left hand type, easily identifiable, as the top blade is either on the right of on the left.
(3) **Curved hand shear:** It is used for cutting circular or irregular curved shapes ranging from 20 to 35 cm.

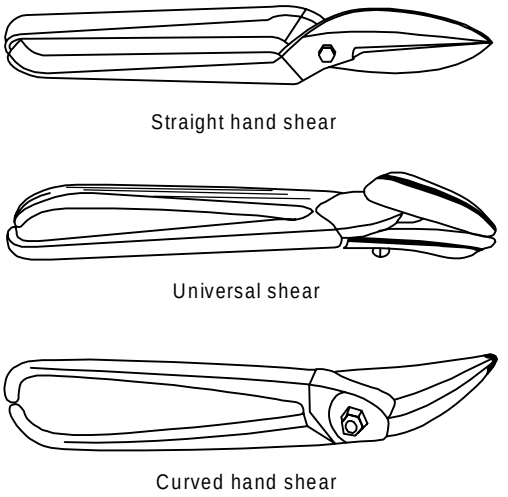
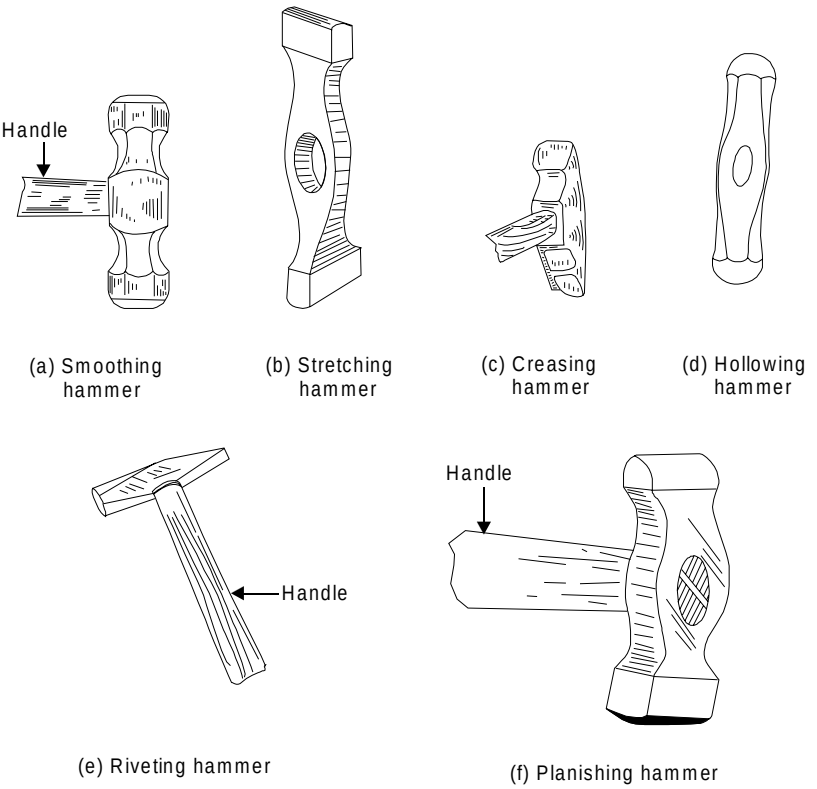


Fig. 18.1 Types of hand shears or snips

18.3.2 HAMMERS

Fig 18.2 shows the various types of hammers used in sheet metal work for forming shapes. The uses of different kind of hammers are given as under:



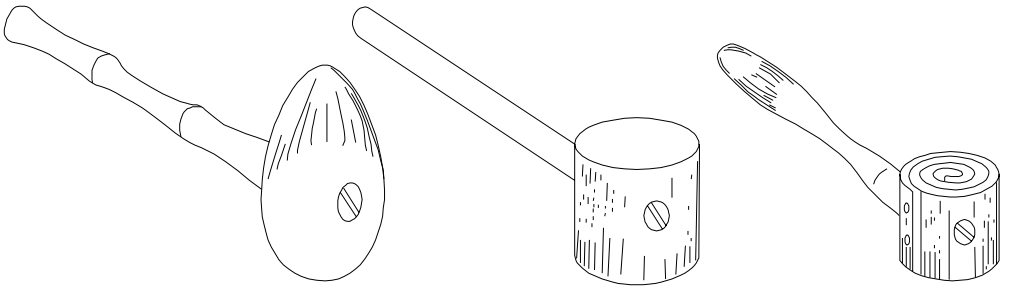


Fig. 18.2 Types of hammers

(*a*) **Smoothing hammer.** Smoothing hammer (Fig. 18.3(a)) is used for leveling and smoothing a sheet metal joint.

(*b*) **Stretching hammer.** Stretching hammer (Fig. 18.3(b)) is used for stretching sheet.

(*c*) **Creasing hammer.** Creasing hammer (Fig. 18.3(c)) is used to close down joint edges of sheets metal part.

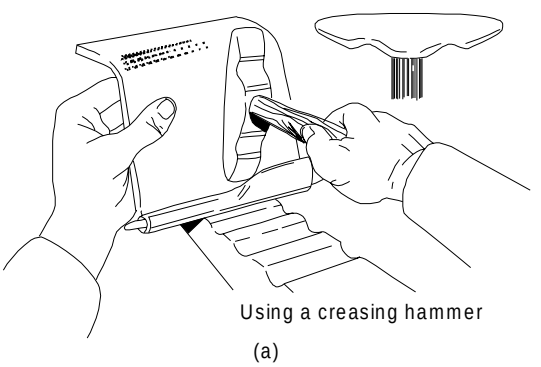
(*d*) **Hollowing hammer.** Hollowing hammer (Fig. 18.3(d)) is used for hollowing sheet metal part. It is used for generating sharp radii also.

(*e*) **Riveting hammer.** Riveting hammer (Fig. 18.3(e)) is used for forming riveted heads.

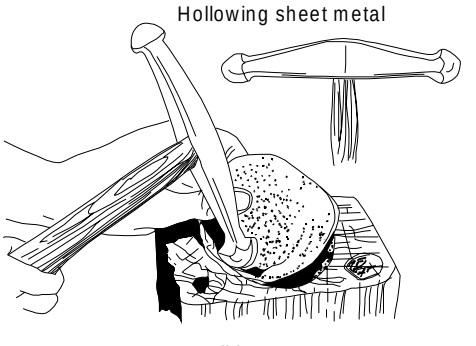
(*f*) **Planishing hammer.** Planishing hammer (Fig.18.3(f)) is used for removing small marks or indentations from the sheet metal job surface and to true the shape of the work. It smoothens off the finished sheet metal work.

(*g*) **Soft hammer or Mallets.** Mallets (Fig. 18.3(g)) used during working with soft metal sheets. They may be of wood, rubber or raw hide. A mallet strikes a blow with the minimum damage to the surface. In sheet metal work, the commonly used mallets are bossing mallet, tinman's mallet (Fig. 18.3(h)) and rawhide mallet (Fig. 18.3(i)).

The uses of hammers for some sheet metal operations are depicted through Fig. 18.3.



(a)



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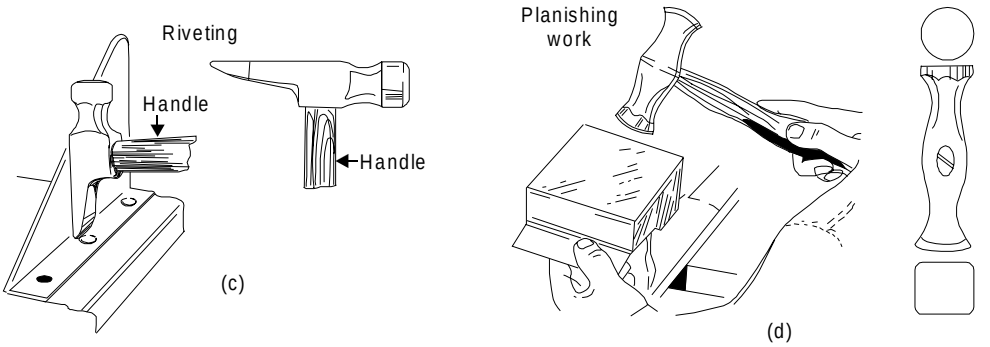


Fig. 18.3 Uses of hammers

18.3.3 Stakes

Stakes are used to form the metal sheets into various shapes. It is a sort of anvil, which supports the sheet for sheet metal work. It consists of a shank and a head or horn. The shank of stake is designed to fit into a tapered bench socket. The head or horn of stake is available in a number of varieties of sizes and shapes. Their working faces of stakes are machined or ground to needed shape. With the help of a hammer, operations such as bending, seaming or forming can be easily performed on these stakes. Some stakes are made of forged mild steel faced with cast steel. Whereas the better class stakes are made either of cast iron or cast steel. Fig 18.4 shows the various types of stakes, which are discussed below:

1. **Beak horn stake.** Beak horn (Fig. 18.4(a)) is basically used for forming, riveting and seaming articles made of sheet metal part. It is not much suitable like blow horn stake. It has a thick tapered horn at one end and a rectangularly shaped horn at the other.
2. **Funnel stake.** Funnel stake (Fig. 18.4(b)) is commonly used for planishing tapered work and hand forming of funnels and similar conical shapes of sheet metal.
3. **Half moon stake.** Half moon stake (Fig. 18.4(c) is basically used for throwing up edges of curved sheet metal work and for preliminary stages of wiring curved edges.
4. **Round bottom stake.** Round bottom stake (Fig. 18.4(d)) is commonly used for squaring up edges and setting up the bottom of cylindrical jobs made up of sheets.
5. **Bick iron.** Bick iron stake (Fig. 18.4(e)) is mainly used for forming taper handles, spouts and tubular work in general. The narrow flat anvil end of bick iron is very useful on rectangular work.
6. **Hatchet stake.** Hatchet stake (Fig. 18.4(f)) is generally used for making sharp bends, bending edges and forming boxes and pans of sheet metal by hand. This stake has a sharp straight edge beveled along one side.
7. **Creasing with horn stake.** Creasing horn stake (Fig. 18.4(g)) has a round horn used for forming conical shaped pieces in sheets. The other end has a tapering square horn with grooved slots for wiring and beading.
8. **Needle case stake.** Needle case stake (Fig. 18.4(h)) is generally used for bending of sheets. It has a round slender horn for forming wire rings and tubes.
9. **Candle mold stake.** Candle mold stake (Fig. 18.4(i)) has two horns for different tapers when forming, seaming and riveting long flaring articles made up of sheet metal.

10. **Blow horn stake.** Blow horn stake (Fig. 18.4(j)) is generally used in forming, riveting and seaming tapered articles such as funnels.
11. **Conductor stake.** Conductor stake (Fig. 18.4(k)) has two cylindrical horns of different diameters. It is used for forming, riveting, and seaming small sized pipes and tubes.
12. **Double seaming stake.** Double seaming stake (Fig. 18.4(l)) consists of two cylindrical horns of different diameters and it is commonly used for riveting forming, and seaming tubes and small pipes.

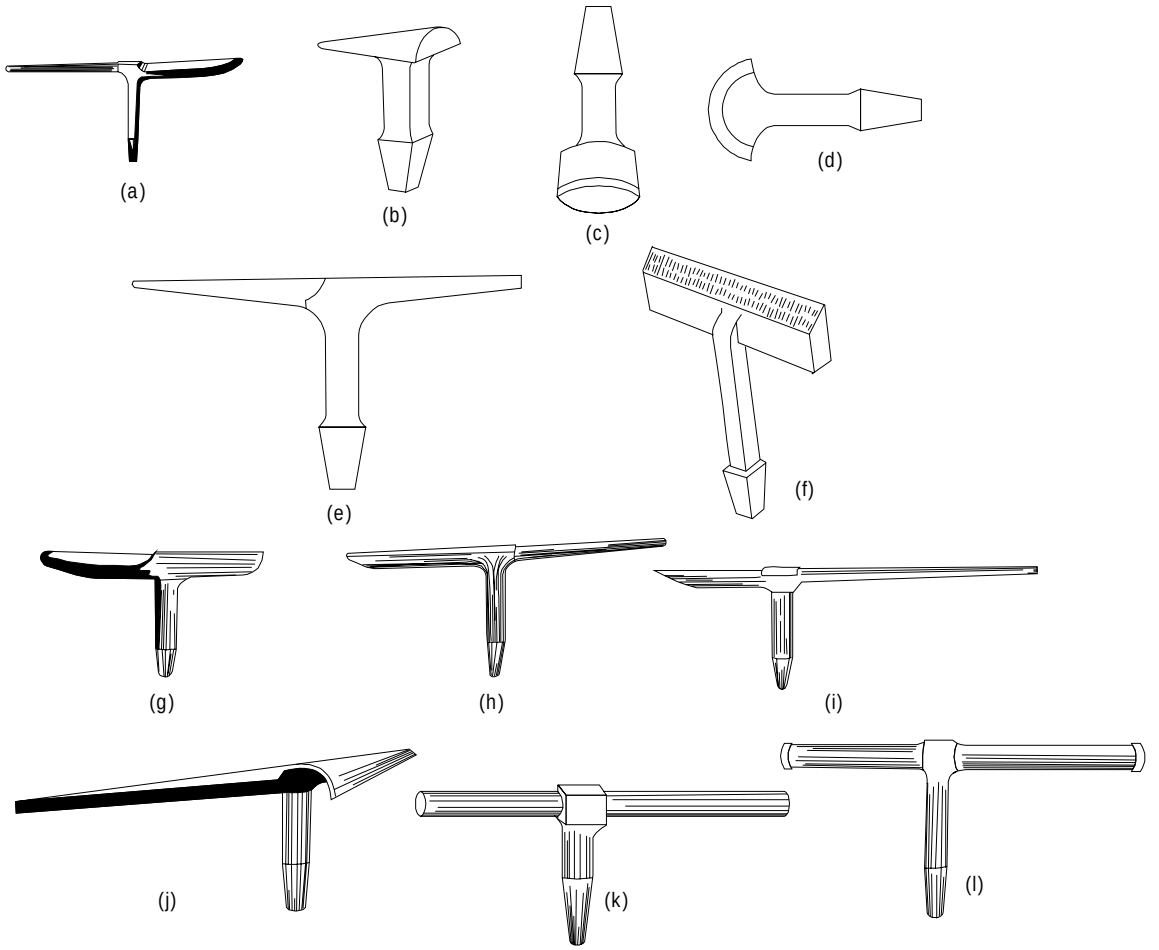


Fig. 18.4 Types of stakes

18.3.4 Stake Holder

Fig 18.5 shows the stake holder, which is a rectangular cast iron plate that has conveniently arranged tapered holes so that the various stakes may fit in and may be used in different positions for tackling the sheet metal job for a particular work.

18.3.5 Cutting Tools

Sheet metal shop uses cutting tools, which are described in detail in the chapter 19 pertaining to fitting work along with relevant figures. Commonly used cutting tools involve

types of files, chisels, scraper and hacksaws. Some of the commonly used cutting tools are discussed as under.

1. **Files.** These are flat, square, round, triangular, knife, pillar, needle and mill types.
2. **Chisels.** The flat chisel and round nose chisel are most widely used in sheet metal work.
3. **Scrapers.** These are flat, hook; triangular, half round types.
4. **Hacksaws.** Hacksaw used in sheet metal shop may be hand hacksaw or power hacksaw.

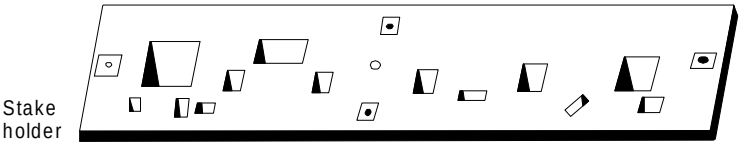


Fig. 18.5 Stake holder

18.3.6 Measuring Tools

There are a fairly large number of measuring tools used in sheet metal shop, which are described in detail along with relevant figures in chapter 19 dealing with fitting work. The most commonly used measuring tools are given as under.

1. Folding rule
2. Circumference rule
3. Steel rule
4. Vernier caliper
5. Micrometer
6. Thickness gauge

18.3.7 Miscellaneous Hand Tools

1. Steel square
2. Straight edge
3. Divider
4. Scriber
5. Trammel points
6. Soldering iron
7. Pliers

Some of the commonly used hand tools are described as under

1. **Folding rule.** It is used in measuring and laying out on sheets larger work with accuracy of 0.5 mm.
2. **Steel rule.** It is useful in measuring and laying out small work on sheets. It can also measure up to accuracy of 0.5 mm.
3. **Tinrnan's mandrel.** The body of tinman's mandrel consists of a flat part and circular parts and serves as a base for carrying out several operations on sheets. The flat part carries a tapered square hole for accommodating the shanks of other stacks. The circular part is required for seaming of pipes and riveting.

4. **Trammel.** Fig. 18.6 shows a typical trammel and its operations. It is long rod called a beam on which are mounted two sliding heads used to hold scribing points for scribing work on sheets. The points are adjustable in nature and can be replaced by pencils, caliper legs or ballpoints. It is a layout generally required to measure between two points or to scribe large circles or arc too long for divider.

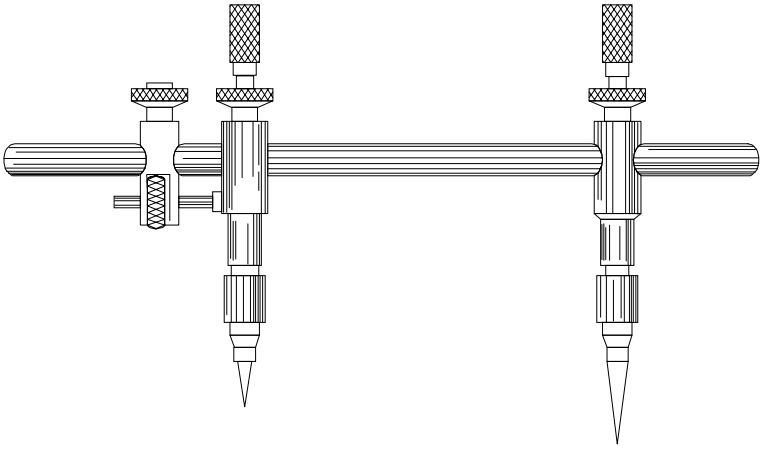


Fig. 18.6 A typical trammel and its operation

5. **Semi-circular protector.** Fig. 18.7 shows the semicircular protractor whose head is circular and back is flat. It is generally used to for setting bevels, transferring angles and other classes of work on metal sheets.

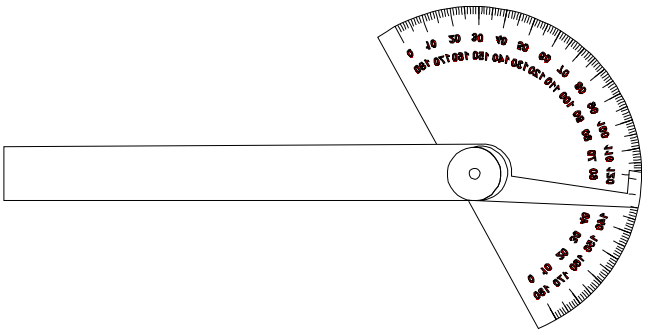


Fig. 18.7 Semi circular protector

6. **Pliers.** Flat nose and round nose type pliers are commonly used for holding the sheet work and forming different shapes respectively.
7. **Scribers.** Fig. 18.8 shows the different kinds of scribers, which are made of hardened steel of 3-5 mm. diameter and 20 cm. long. Its one end is pointed as sharp as possible for making scribing lines on metal sheets.

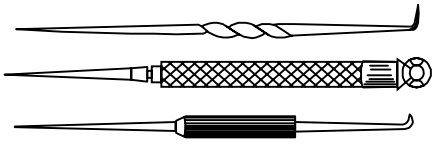


Fig. 18.8 Various types of scribers

8. **Groover.** Fig. 18.9 shows a typical groover and its operation, which consists of two folded edges called locks. The two edges are hooked together and locked with a grooving tool called hand groover. These tools come with grooves of various width and vary in size. The groover is used for offsetting an outside grooved seam. Initially, the folding edges to 180° are made first. Then the folded edges are hooked together. Finally grooving tool is then used to make strong joint of metal sheets as shown in figure.

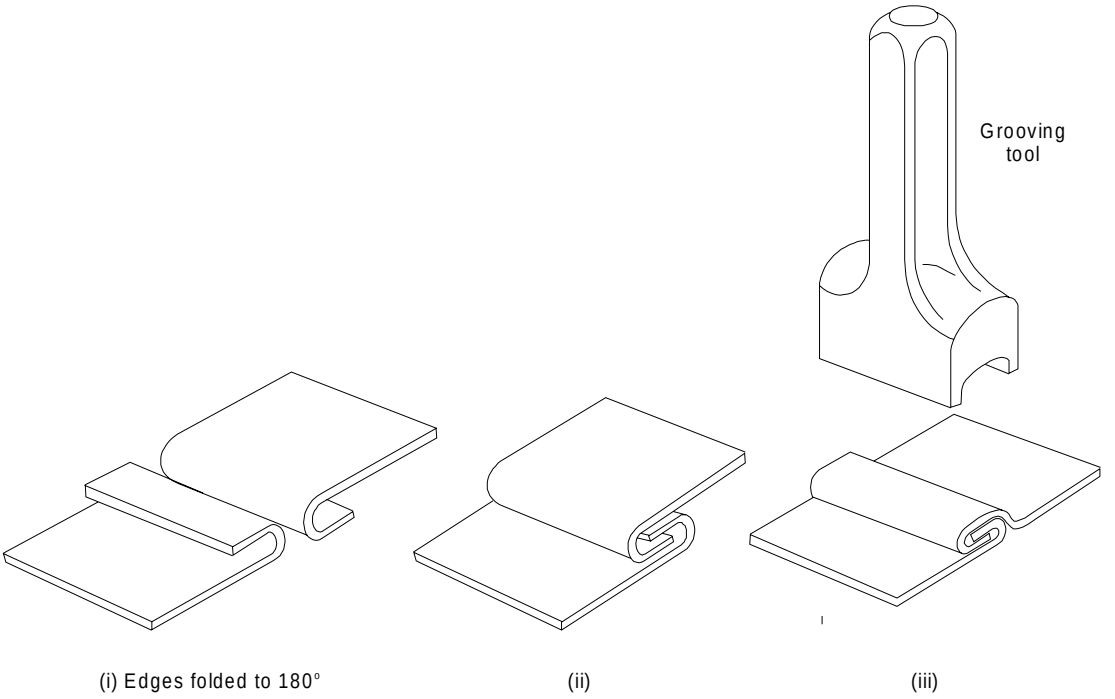


Fig. 18.9 A typical hand groover and its operation

9. **Hand seamer.** Fig. 18.10 shows a hand seamer, which is used for bending narrow portions, which are difficult to fold, by other means. It has two adjustable screws, which can be regulated for width of bend. The metal sheet is placed between the jaws and the jaws are clamped together by squeezing the handles to grip the sheet for further bending.

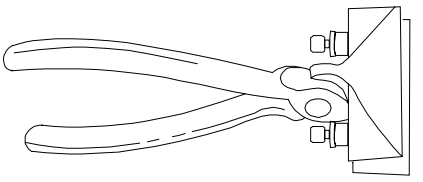


Fig. 18.10 Hand seamer

Other hand tools or instruments used in sheet metal shop include rivet sets, soldering iron, scrapers clamps, screw drivers, spanners and wrenches, chisels, different types of calipers and dividers, vernier caliper, micrometers, standard wire and thickness gauges, files for softer metals, conventional types of metal files including needle files and round files.

18.4 FOLDING TERMINOLOGY OF SHEET METAL JOINT

18.4.1 Edge

The edges on part need to be folded to increase the strength and to eliminate the sharp edges of sheet metal component.

1. **Types of folded edges.** The common types of folded edges are: (*i*) single hem, (*ii*) double hem and (*iii*) wired edge
2. **Single hem.** It is made by folding the edge over. To layout such a hem, a line is drawn at a distance equal to the desired hem width.
3. **Double hem.** It is a single hem with its end bent under. To layout such a hem, draw two parallel lines each equal to the width of the hem.
4. **Wired edge.** It consists of an edge, which has been wrapped around a piece of wire. This edge is used where more strength is needed. To layout wired edge the diameter of wire is to be determined. The steel metal will be needed to roll around the wire.

18.4.2 Seam

A seam is the section where pieces of sheet metal are joined together. Most common types of seams are:

(*a*) Single seam, (*b*) Double seam, (*c*) Grooved seam, (*d*) Lap seam, (*e*) Dovetail seam, and (*f*) Burred bottom seam

1. Single seam

It is used to join a bottom to vertical bodies of various shapes. To layout such a seam, draw a line parallel to one edge of the sheet metal body stretch out at a distance equal to the width of the seam. Now draw two lines parallel to the edges of the bottom stretch out. The first line should be drawn at the distance from the edge of sheet metal equal to the width of the seam minus 1 mm. approx. Second line should be drawn at a distance from the first equal to the width to the seam on sheet metal plus 1 mm approx. The plus and minus dimensions of 1 mm is used to prevent the folded bottom edge of sheet metal from interfering with the body's folded bottom edge. If the bottom is round, then mark the lines on sheet metal part.

2. Double seam

The layout process for this seam on sheet metal part is similar to that used for a single seam on sheet metal part. It differs from single seam in a manner that its formed edge is bent upward against the body.

3. Grooved seam

It is made by booking two folded edges of sheet metal part together and then off-setting the seam as shown in Fig. 18.19. On one piece draw one line equal to half the width of the seam from outer edge. Then draw second line at a distance equal to the width of the seam from the first line. Same way draw two lines on the other piece of sheet metal part.

4. Lap seam

It is the simplest type of seam made on sheet metal part because one edge laps over another and is soldered or riveted. To layout lap seam on sheet metal part, draw line on the edge of piece at a distance equal to the width of the required seam.

5. Dovetail seam

It is used to join a flat plate to a cylindrical piece. To layout such a seam, draw a line parallel to one edge of sheet metal component at a distance of 6 to 20 mm. depending upon the size of the hole of sheet metal part. Then draw lines to indicate where the sheet metal part is to be slit. The width of the piece between slits ranges from 6 to 26 mm.

6. Flanged or burred bottom seam

It is used to fasten the bottom of a container made of sheet metal to its body in which upper part is the sheet metal body and lower bottom of a container. To layout such a seam on sheet metal part, draw a circle, which represents the outline of the bottom on sheet metal part. If it is square or rectangular component, draw the bottom shape on the sheet metal part. Then draw a second line to show the width of the flange. The width of this flange may range from 3 to 6 mm on sheet metal part.

18.4.3 Notches

In the process of laying out on sheet metal part, some provision is to be made for bent sections when they have folded edges. The opening left at corners of seams and edges of sheet metal part are called notches. Five common types of notches are: (1) Straight notch, (2) V-notch, (3) Square notch and (4) Slant notch.

1. **Straight notch.** It is prepared by making a straight cut where the bend is to occur in sheet metal part.
2. **V-notch.** It is used where the corners of a flange should fit together in sheet metal part. It is used for laying out 90° and other than 90° angle on the sheet metal part
3. **Square notch.** It is applicable where square or rectangular box (made up of sheet metal) is formed.
4. **Slant notch.** It is used where single hems are to meet at right angles. In this process they should be clipped at 45° angle on the sheet metal part.

18.4.4 Folded Sheet Metal Joints

As per requirements, various types of sheet metal joints are used in sheet metal work. Such joints are commonly used to fasten bottoms to cylinders, square or rectangular containers. Some of the commonly used such joints are shown in Fig. 18.11.

1. **Lap joint.** It is very frequently used in sheet metal work and can be prepared by means of soldering or riveting.
2. **Seam joint.** This joint is a very generally used in sheet metal work. It is locked, as shown in the diagram, so as to ensure a positive grip and also to make the joint flush with the surface.

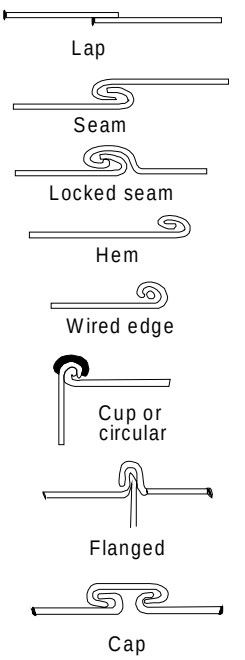


Fig. 18.11 Various sheet metal joints

3. **Locked seam joint.** This joint is used for locking seam joints in sheet metal work.

4. **Hem (single and double), wired edge, cup and angular joints.** These enable the edges sheet metal part to join the pieces along them.
5. **Flanged joint.** It is commonly used in sheet metal work frequently in making pipe connections.
6. **Cap joint.** It provides another useful form of locked seam joint on sheet metal component with good appearance and strength. It is generally used for assembling cross seam of ducts made up of in sheet metal part.

18.5 SHEET METAL OPERATIONS

The major sheet metal operations carried out in sheet metal work are as follows:

1. Cleaning
2. Measuring
3. Marking
4. Laying out
5. Hand cutting
6. Hand shearing
7. Hand forming
8. Edge forming
9. Wiring
10. Joint making
11. Bending
12. Drawing
13. Soldering
14. Circle cutting
15. Machine shearing
16. Nibbling
17. Piercing
18. Blanking

The measuring and marking operations carried over on sheet metal are discussed as under.

Measuring and Marking

The standard sizes of metal sheets available in the market are quite large. But the required sheet size for making a component may be smaller and hence a standard size sheet may have to be therefore cut into several smaller pieces. Each piece must be sufficient for making one such component as per the needed size. Smaller sizes of sheet metal part are first decided and are then marked on the larger metal sheet to cut the latter into small pieces along the marked lines. A little allowance for cutting is always incorporated to the required overall sizes. The overall dimensions of the required smaller sizes are marked on the larger sheet with the help of marking tools such as a steel rule, a straight edge, a steel square and a scriber. The sheet surface may have to be coated with a coloring media so that the scribed lines arc clearly visible. If circular pieces are needed, a divider or trammel may be used to mark the circles.

18.6 DEVELOMENT OF PATTERN LAYOUT

Projective geometry forms the basis of successful layout of patterns for making different jobs in sheet metal work. Most of the patterns are obtained from development of surfaces of some common geometrical solids like cylinder, prism, pyramid and cone. These shapes may be required to be developed either in single or in combination. A sheet metal planner should have a thorough idea of the procedures employed in developing the surfaces of the above solids and their inter-penetrations.

Sheet metal work consists mainly of cutting, forming and assembling the object that has been laid out on flat metal sheet. The outline of the object or pattern is first either scratched on the sheet or drawn on a paper and then transferred to the sheet. Metal sheet is then cut to various shapes and sizes as per the pattern or shape of object, which may be later, transformed to various articles by using different sheet metal processes. In the process of laying out a pattern, certain allowances are kept for making edges and seams. The development of surface is the unfolding or unrolling sheet in one plane. The sheet is used to mark correctly using scriber. Important attention is also invited regarding accounting for the allowance in preparing edges and seams to be made for making joints. The notches of metal pieces are then cut. Finally the edges are then turned to form box as shown through step in Fig. 18.12.

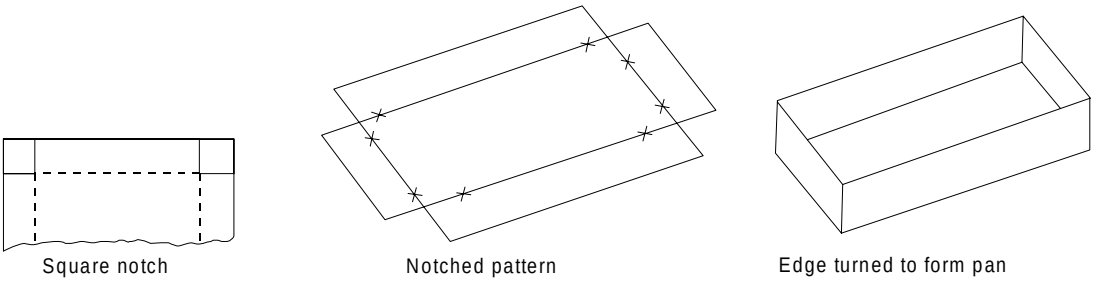


Fig. 18.12 Pattern development of sheet metal part

18.7 MACHINES USED IN SHEET METAL SHOP

The various machines, which are in use to perform different operations on metal sheets, can be listed as follows:

1. Shearing machine
2. Bending machine
3. Folding machine
4. Grooving machine
5. Peining machine
6. Beading machine
7. Swaging machine
8. Burring machine
9. Double seaming machine

Apart from the above, many other special purpose machines are also manufactured to suit a particular kind of work especially in mass production of identical parts. The above machines vary in shape and also slightly in the procedure of operating according to the mechanism adopted by different manufactures. Some important machines are discussed as under.

A shearing machine consists of a base or frame, which can be conveniently fixed on a bench in any position as desired. Two shearing blades are provided in the machine. One called the fixed blade is rigidly fixed with the frame whereas the other known as movable blade is operated by means of the hand lever provided at the rear. In operation, the metal sheet is placed between the shear blades in such a way that the markings of the layout come exactly under the cutting edge of the upper blade. Out of the two blades one is fixed and the other

moveable. When the lever is pulled by the operator the lower blade rises and thus the metal sheet is cut. This particular provision enables the metal sheet to be locked against the upper blade during the operation on account of the circular motion of the hand lever. With the result, the metal sheet is prevented from being distorted.

Folding machines are used for bending and folding the edges of metal plates to form the joint at the seam. Bending machines or bending rollers, as they are better known, are used for shaping metal sheets into cylindrical objects. The machine consists of three rollers. These rollers have different adjustments indifferent types of machines. In some-machines two rollers at the bottom have fixed position and the third one (top roller) can be adjusted in vertical direction to adjust the pressure and give the required curvature to the sheet. A still better control is obtained by having two rollers exactly one over the other, out of which the bottom roller is fixed and the top roller can be adjusted vertically to suit the thickness of the sheet and the pressure required for rolling. The third roller, called radius roller can be moved up and down to provide the desired curvature. Improved designs of these machines are available which contain the rollers, which have grooves of various shapes and sizes to form corresponding shapes in metal sheets. Conical shaped rollers are used for tapered cylindrical articles. Similarly other machines named above are used to perform different operations after which they are named.

Burring machine is used to make a burr on the edges of the bottom and covers. Burr is the starting of the seam. Double seaming machine is used for double seaming flat bottoms on straight or flared cylindrical pieces.

Various types of press machines with different capacities are used for mass production of sheet metal components. These are equipped with different kind of press tools or dies. These are commonly employed for fast and accurate processing of sheet metal work.

18.8 TYPE OF PRESSES

Presses are classified based upon the method of operation method of power source method of activation of slide and number of slides in action. The sub-classification of each is also gien as under.

1. Method of Operation

(*i*) **Arbor Press.** It is a hand operated press. It combines the principle of lever with pinions to a related rack build into the ram. They are used where a very limited no. of production of parts is required.

(*ii*) **Foot Press.** It is also manual operated press. Most of the presses have foot action in their operating mechanism.

(*iii*) **Open back inclinable press.** It is a power operated press. They are having bench or floor models.

Presses are classified according to

2. Method of Power Sources

(*i*) Manual presses

(*ii*) Mechanical power presses

(*iii*) Hydraulic presses.

3. Method of Activation of Slide

(*i*) Crank shaft presses

(*ii*) Knuckle joint presses

(*iii*) Toggle presses

4. Number of Slides in Action

(*i*) Triple action single action presses

(*ii*) Double action presses

18.9 GENERAL PRESS INFORMATION

It is necessary for the sheet metal planner to know certain fundamentals specification of press machine. Some of them are press tonnages, stroke of the press, die area, shut height etc., and are explained below.

Press tonnage

It indicates the amount of pressure in tones that a press exerts or works safely and is used for rating a press. The press may exist in various capacities of tones varying from 5, 10, 20, 32, 50, 75, 200, 500 tons to tackle the sheet metal operation using proper die in press. The tonnage of a hydraulic press is the area multiplied by the oil pressure in the cylinder. The tonnage of a mechanical press is equal to the shear strength of the crankshaft metal multiplied by the area of the crankshaft bearings.

Press stroke

It is the reciprocating motion of a press slide. It is adjustable on a hydraulic press.

Die area

It is the available surface for mounting punches and die components

Shut height

It is the distance from the top of the bed to the bottom of the slide when stroke down and the adjustment up. The shut height of the die must be equal to or less than the shut height of the press.

Die shut height = Punch shoe thickness + Die show thickness + Die steel height + Punch steel Height-bypass of steels. The by-pass of steels may be taken as from 3 mm to 6 mm.

18.10 GENERAL PRESS OPERATIONS

1. **Shearing.** It takes place in form a cut when punch strikes and enters in the sheet placed on die. The quality of the cut surface is greatly influenced by the clearance between the two shearing edges of the punch and dies.
2. **Cutting.** It means severing a piece from a strip or sheet with a cut along a single line using suitable punch and die of press tool in press machine.
3. **Parting.** It signifies that scrap is removed between the two pieces to part them using suitable punch and die of press tool in press machine.

4. **Blanking.** It is a operation in which the punch removes a portion of material called blank from the strip of sheet metal of the necessary thickness and width using suitable punch and die of press tool in press machine.
5. **Punching.** It is the operation of producing circular holes on a sheet metal by a punch and die. The material punched out is removed as waste. Piercing, on the other hand, is the process of producing holes of any desired shape in the part or sheet using suitable punch and die of press tool in press machine.
6. **Notching.** It is a process to cut a specified shape of metal from the side or edge of the stock using suitable punch and die.
7. **Slitting.** When shearing is conducted along a line, the process is referred to as slitting. It cuts the metal sheet lengthwise using suitable punch and die of press tool in press machine.
8. **Lancing.** It makes a cut part way across a sheet and creates a bend along the cut using suitable punch and die.
9. **Nibbling.** It is an operation of cutting any shape from sheet metal without special tools. It is done on a nibbling machine.
10. **Trimming.** It is the operation of cutting away excess metal in a flange or flash from a sheet metal part using suitable punch and die of press tool in press machine.
11. **Bending.** Bending is the operation of deforming a sheet around a straight axis. The neutral plane lies on this straight axis. In bending all sheet material are stressed beyond the elastic limit in tension on the outside and in compression on the inside of the bend. There is only one line, the natural line that retains its original length. The neutral axis lies at a distance of 30 to 50% of thickness of the sheet from the inside of the bend. Stretching of the sheet metal on the outside makes the stock thinner. Bending is sometimes called as forming, which involves angle bending, roll bending, roll forming, seaming and spinning.

18.11 QUESTIONS

1. Explain various hand tools used in sheet metal work?
2. Name the metals commonly used in sheet metal work.
3. Write short notes on:
   (*a*) Punching (*b*) Piercing
   (*c*) Blanking (*d*) Slitting
   (*e*) Bending (*f*) Lancing
4. Discuss the different sheering operations performed on sheet metal.
5. Explain the difference between punching, blanking and piercing.
6. Discuss the various types of hammers used in sheet metal work.
7. Describe the process of bending.
8. Write short notes on:
   (*a*) Drawing (*c*) Shearing
   (*d*) Riveting (*e*) Hollowing
   (*f*) Planishing
9. Name various tools, machine and equipments used in sheet metal shop.

19 CHAPTER

FITTING

19.1 INTRODUCTION

These days small, medium and heavy industries are using automatic machines. But bench and fitting work also plays a significant role for completing and finishing a job to the desired accuracy. Most of semi-finished works can be accomplished with fairly good degree of accuracy in a reasonable time through various kinds of quick machining operations. They still require some minor operations to be performed to finish the job by hand. The term bench work denotes the production of an article by hand on the bench. Where as fitting is the assembling of parts together and removing metals to secure the necessary fit, and may or may not be carried out at the bench. These two types of work require the use of a large number of hand tools and other devices or equipments that involve a number of operations for accomplishing the work to the desired shape and size. Some of the commonly used tools are discussed as under.

19.2 TOOLS USED IN FITTING SHOP

Tools used in bench and fitting shop are classified as under.

1. Marking tools
2. Measuring devices
3. Measuring instruments
4. Supporting tools
5. Holding tools
6. Striking tools
7. Cutting tools
8. Tightening tools, and
9. Miscellaneous tools

The above mentioned tools are further classified and discussed as under.

1. Markeing Tools

These are sub classified as steel rule, circumference rule, straight edge, flat steel square,

scriber, semi-circular protractor, divider, trammel, prick punch, centre punch, try square, bevel square, vernier protractor, combination set and surface gauge.

2. Measuring Devices

Commonly used measuring devices and instruments used in bench and fitting shop are fillet and radius gauge, screw pitch gauge, surface plate, try square, dial gauge, feeler gauge, plate gauge and wire gauge.

3. Measuring Instruments

Line measuring and end measuring devices. While using line measuring device, the ends of a dimension being measured are aligned with the graduations of the scale from which the length is read directly such as scales or steel rules. Whereas, with end measuring device, the measurement is taken between two ends as in a micrometer, vernier calipers and gauge block, etc. End measuring devices are commonly used for measuring accurate and precision dimensions of components. Some measuring instruments are employed for measuring linear dimensions and others are suitable for determining angular or geometric dimensions. Few measuring instruments are also kept for reference purposes as standards of comparison. The main measuring instruments are listed as under.

(*i*) Linear measurements

(A) Non-precision instruments

1. Steel rule
2. Calipers
3. Dividers
4. Telescopic gauge
5. Depth gauge

(B) Precision instruments

1. Micrometers
2. Vernier calipers
3. Vernier depth gauges
4. Vernier height gauges
5. Slip gauges

(C) Comparators

(D) Coordinate measuring machines

(*ii*) Angular measurements

(A) Non-precision instruments

1. Protector
2. Engineers square
3. Adjustable bevel
4. Combination set

(B) Precision instruments

1. Bevel protector
5. Angle gauges
6. Sine bar
7. Clinometers
8. Autocollimators
9. Sprit level

(*iii*) Surface measurement

1. Straight edge
2. Surface gauge
3. Surface table
4. Optical flat
5. Profilo-meter

4. Supporting Tools

These are vee-block, marking table, surface plate, and angle plate.

5. Holding Tools

These are vices and clamps. Various types of vices are used for different purposes. They include hand vice, bench vice, leg vice, pipe vice, and pin vice. The clamps are also of different types such as c or g clamp, plane slot, goose neck, double end finger, u-clamp, parallel jaw, and clamping block.

6. Strking Tools

These are various types of hammers such as ball peen hammer; straight peen hammer; cross-peen hammer; double face hammer; soft face hammer.

7. Cutting Tools

These involve various types of files, scrapers, chisels, drills, reamers, taps, snip or shear and hacksaws.

Files. There are different types of files such as flat, square, round, triangular, knife, pillar, needle and mill.

Scrapers. These are flat, hook, triangular, half round types.

Chisels. There are different types of chisels used in fitting work such as flat chisel, cross cut chisel, diamond point chisel, half round chisel, cow mouth chisel and side cutting chisel.

The other cutting tools are drills, reamers, taps, snips, hacksaws (hand hacksaw and power hacksaw) etc.

8. Tightening Tools

These are pliers and wrenches, which are sub classified as under.

Pliers. These are namely ordinary, needle nose, and special type.

Wrench. These are open single ended, open double ended, closed ended adjustable, ring spanner, offset socket, t- socket, box wrench, pipe wrench and allen wrench.

9. Miscellaneous Tools

These are die, drifts, counter sink tools, counter boring tools, spot facing bit and drill press.

Some of above mentioned important tools are discussed as under.

19.2.1 Measuring Tools

19.2.1.1 Steel Rule

Steel rule is generally employed for purpose of measuring rough dimensions and laying out them. It is always advisable to start measuring from 1 cm mark because the end of the rule is generally worn out

19.2.1.2 Circumference Rule

It is commonly used for measuring or laying out or as a straight edge. The specialty in this rule is that the circumference can be taken directly, below the diameter dimension.

19.2.1.3 Straight Edges

There are two types of straight edges namely four edge type (Fig. 19.1(a)) and bridge type (Fig. 19.1(b)) which are made of carbon tool steel and alloy steel. They are generally flat graduated bar of steel with one longitudinal edge beveled. Straight edges come in various lengths commonly varying from 2.5 mm up to one meter and above. They are mostly used for scribing long straight lines.

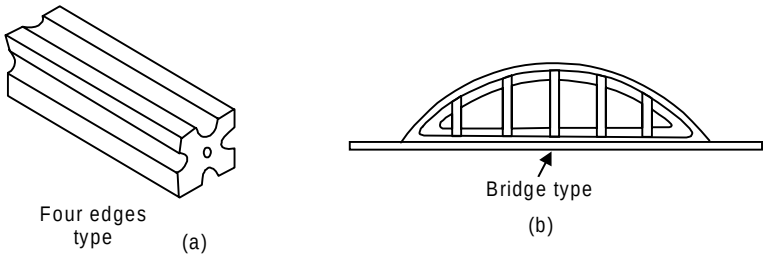


Fig. 19.1 Straight edges

19.2.1.4 Flat Steel Squrae

It is a piece of flat hardened steel with graduations on either end. It is commonly used for marking lines in the perpendicular direction to any base line.

19.2.1.5 Scribers

Fig. 19.2 shows the various types of scribers, which are sometimes called the metal worker's pencil. These are made up of high carbon steel and are hardened from the front edge. Scriber is used for scratching lines on the sheet metal during the process of laying out a job.

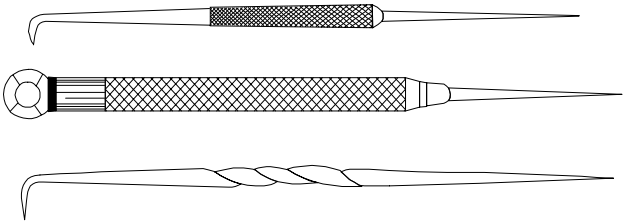


Fig. 19.2 Scribers

19.2.1.6 Bever Protractor

The bevel protector (Fig. 19.3) is an instrument used for testing and measuring angles within the limits of five minutes accuracy. The common components of this instrument are base, disc which is fitted with a pivot at the centre and carries a datum line. On this pivot of the protector, the dial is allowed to rotate when the clamping nut is released. The other unit clamps the blade rigidly to the dial. The blade can be moved lengthwise. Vernier scale is also provided on the disc to take reading for accurate measurement. Dial is graduated in degrees over an arc.

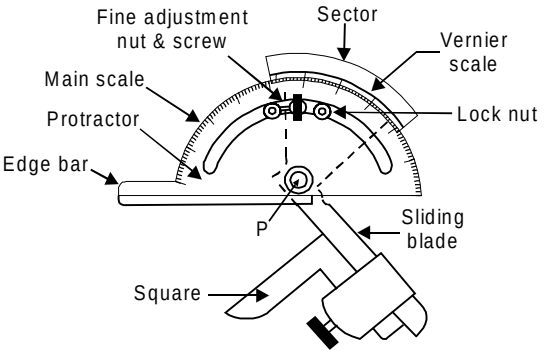


Fig. 19.3 Bevel protector

19.2.1.7 Divider

It is used for marking and drawing circle and arcs on sheet metal.

19.2.1.8 Trammel

Trammel is used for marking and drawing large circles or arcs, which are beyond the scope of dividers.

19.2.1.9 Prick Punch

Fig. 19.4 shows the prick punch, which is used for indentation marks. It is used to make small punch marks on layout lines in order to make them last longer. The angle of prick punch is generally ground to 30° or 40° whereas for centre punch it is kept 60 °or 90°.

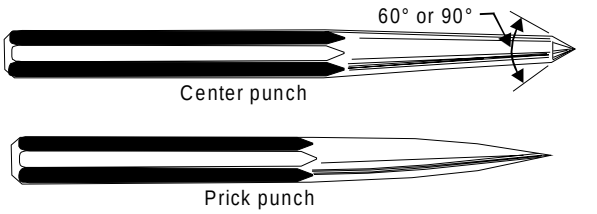


Fig. 19.4 Typical prick and centre punch

19.2.1.10 Centre Punch

Fig. 19.4 shows the centre punch, which is used for locating centre for indentation mark for drilling purposes.

19.2.1.11 Surface Gauge or Scribing Block

Fig. 19.5 illustrate the surface gauge which is a principal marking tool used generally in the fitting and the machine shops. It is made in various forms and sizes. It consists of a cast iron sliding base fitted with a vertical steel rod. The scriber or marker is positioned or set into an adjustable device using a knurled nut at one end. The scriber can be loosened or tightened by means of the nut. The marker is used to set it at any desired inclination, moved to and fro inside the hole accommodating it or adjust its height along the vertical pillar. It is commonly used in conjunction with either a surface plate or marking table. It is used for locating centres of round rod held in V- block, describing straight lines on work held firmly in its position by means of a suitable device like angle plate and also in drawing a number of lines parallel to a true surface. This device is a very simple form of surface gauge and it is largely being replaced by a more accurate instrument called universal surface gauge.

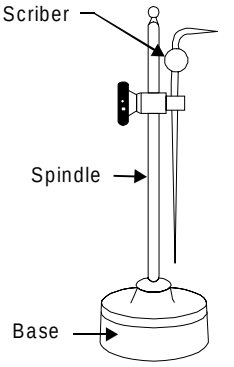


Fig. 19.5 A surface gauge or scribing block

19.2.1.12 Universal Surface Gauge

Fig. 19.6 shows the universal surface gauge, which is an improved variety of the surface gauge simple scribing block. It is designed in such as way that appreciably finer adjustments can be made very quickly. It consists of a cast base perfectly machined and ground at the top, bottom and all sides. The base of the gauge usually carries a V-shaped slot at the bottom so as to render it suitable for use on round objects. Two guide pins are provided at the rear end of the base, which can be pressed down to project below the base of the gauge. These pins can also be used against the edge of the surface plate or any other finished surface for guiding the instrument during marking and scribing work. A swivel bolt is provided at the top of the base in which the spindle is fitted. This spindle can be swung and locked in any desired position by means of the adjusting screw, which is provided with a knurled nut at its end for this purpose. For marking purposes, the scriber is fitted in an adjustable screw on the spindle and is capable of being adjusted at any inclination and height along the spindle. A rocker is provided at the top of the base and it carries an adjusting screw at its rear end. During operation, the spindle is secured in the swivel bolt and is set at a desired inclination. The adjustable scriber is swiveled and set at approximately the required height. On bringing the point of the scriber at the exact correct height, finer adjustments are then made using adjusting screw provided on the rocker. Therefore, this gauge is commonly employed for scribing parallel lines at desired heights from a plane surface, comparing the trueness of two similar heights, setting out a desired height and similar other operations, and forms an indispensable instrument of bench work.

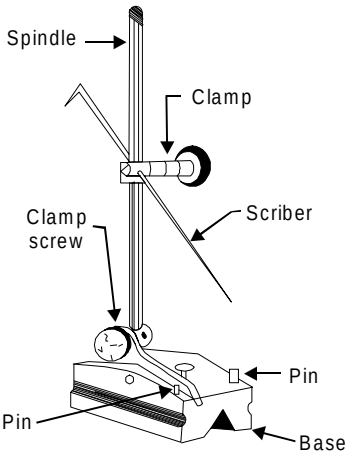


Fig. 19.6 A universal surface gauge

19.2.2 Measuring Devices

There are some general purpose measuring devices such as fillet and radius gauge, screw pitch gauge, surface plate and try square which are described as under.

19.2.2.1 Fillet and Radius Gauge

Fig. 19.7 shows the fillet and radius gauge, which is similar in construction to a screw pitch gauge and carries a similar metal case containing a number of steel blades in it. One set of blades, mounted on one end of the case carries concave end faces and the other set at the other end of the case, carries blades, which have convex end formations. The radii of the curvatures of the end formations are of different dimensions and thus provide a fairly wide range for quick checking and measuring of curvature. This instrument is highly useful for measuring and checking the inside and outside radii of fillets and other round surfaces. The fillet and radius gauges are made in thin strong strips curved to different radii at end. The use of this gauge is depicted through Fig. 19.8.

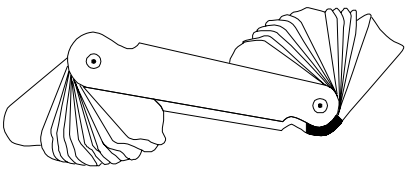


Fig. 19.7 A fillet and radius gauge

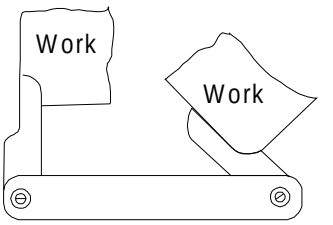


Fig. 19.8 A use of fillet and radius gauge

19.2.2.2 Screw Pitch Gauge

Fig. 19.9 shows the screw pitch gauge, which is a highly fool-proof, very effective and fairly accurate instrument used to identify or check the pitch of the threads cut on different threaded items. It consists of a case made of metal carrying a large number of blades or threaded strips which have teeth of different pitches, cut on their edges and markings corresponding to these pitches on their surfaces. In operation, different blades are applied or tried on the threads one after the other and when any one of them is found meshing with the cut teeth, the relevant reading is read directly from the marking on the matching blade surface. This gauge can be commonly used to measure or check the pitches of both external and internal threads. The free ends of the screw pitch gauge blades are generally made narrow for enabling them to enter the hollow parts easily while checking the internal threads. In some instruments, the blades are made to have markings both for the pitches as well as a value equal to double the depth of the threads. The latter quantity helps in determining quickly the drill size to be used before tapping.

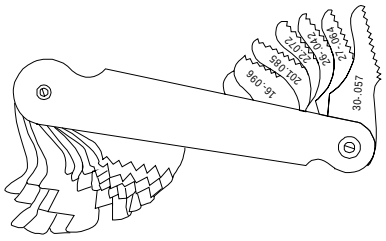


Fig. 19.9 A screw pitch gauge

19.2.2.3 Surface Plate

Fig. 19.10(a) shows the surface plate, which is a cast iron plate having generally a square top well planed and square with adjacent machined faces. The top surface of the plate is finished true by means of grinding and scrapping. It possesses a cast iron base, which is also

machined true to keep the top surface of the plate in a perfect horizontal plane. Its specific use is in testing the trueness of a finished surface, testing a try square, providing adequate bearing surface for V-block (Fig. 19.10(b)) and angle plates, etc. in scribing work.

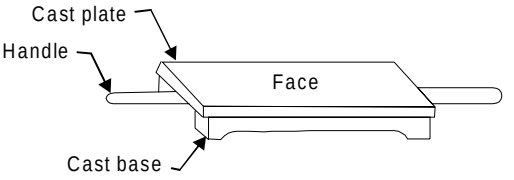


Fig. 19.10(a) A surface plate

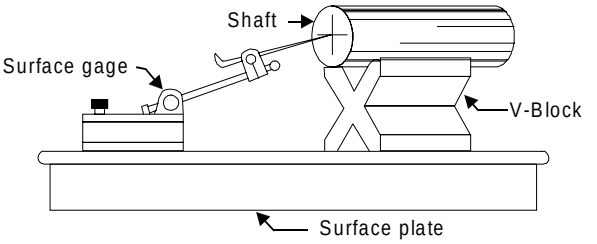


Fig. 19.10(b) A use of surface plate and v-block

19.2.2.4 Try Square

Fig. 19.11 shows the try square, which is also known as engineer's try square. It is very important tool required for scribing straight lines at right angles to a true surface or testing the trueness of mutually normal surfaces. It is made in different sizes out of steel pieces. In construction, it is similar to a carpenter's try square but is comparatively more accurate. It can be made either in one piece or in two pieces. It consists of a steel blade fitted into a steel stock of rectangular cross-section. It is sufficiently hardened and tempered to suit the need. Some precision kind of try squares is made with their blades having beveled edges properly ground and finished square. Both inner and outer surface of the blade are kept truly at right angles to the corresponding surfaces of the stock. In order to maintain this trueness, this tool should be handled with due care and should never be used as a striking or supporting tool or other work. The accuracy of this tool should be frequently checked to ensure the trueness as it affects the accuracy of the finished job to a significant extent.

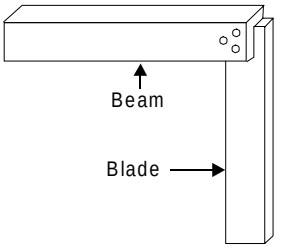


Fig. 19.11 A try square

For checking the accuracy or trueness of a try square, the try square is made to lie flat on the top surface of a surface plate with the stock touching a machined edge of the plate. A straight line is marked along the outer edge of the blade and then the square turned over to take a new position. Another straight line is described along the outer edge of the blade in this new position of the try square. If both lines coincide with each other as they seems to be as one line only, then the try square can be said as true.

19.2.3 Measuring Instruments

Some common measuring instruments generally used in bench work or fitting shop are micrometer, vernier caliper, depth gauge, and vernier height gauge. These are discussed as under.

19.2.3.1 Micrometers

The micrometers are commonly employed for measuring small dimensions with extreme accuracy of 0.01 mm. They may be of the three kinds -

(*a*) External micrometer for measuring external dimensions,

(*b*) Internal micrometer for measuring internal dimensions, and

(*c*) Depth micrometer for measuring depths.

For measuring a dimension in external micrometer, the work piece is held between the fixed anvil face and the spindle face of the micrometer. The spindle of the micrometer is allowed to move linearly towards the work by rotating thimble. When the spindle will touch the work piece properly, the ratchet will give its sound. The small locking lever is then rotated to clamp the spindle so that reading can be taken more accurately. Outside micrometers are used for measuring the outside dimensions of jobs, such as diameter of a bar, rod and thickness of plate. Generally, until and unless they are provided with the vernier attachment, the former can read up to 1/1000 or 0.001 inch and the latter up to 0.01 mm. The former are known as inches micrometers and the latter metric micrometers, which are gradually replacing the former due to the introduction or adopting of metric system. Inside micrometers are commonly used for measuring inside dimensions of the objects, such as inside dia. of a hole, width of a slot or cavity, etc. The outside micrometers are the most extensively used in industrial applications. All the micrometers, irrespective of the fact as to whether they carry graduations in inches or millimeters, are similar in construction. An out side micrometer is discussed as under.

OUTSIDE MICROMETER

Fig. 19.12 shows an outside micrometer. It consists of the following main parts.

1. Metallic frame
2. Axial graduated sleeve
3. Circumferential screwed spindle
4. Hardened steel anvil
5. Thimble
6. Ratchet stop screw
7. Lock nut

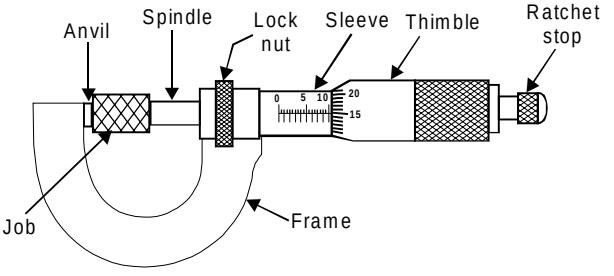


Fig. 19.12 Outside micrometer

Micrometer works commonly on the principle of nut and bolt assembly. The sleeve carries inside threads at the end, which forms the nut, and the screwed part of the spindle passes through it. The spindle and the thimble are secured to each other such that by rotating

the thimble the spindle rotates. With the result, when the thimble is revolved, it advances towards or retards away from the fixed anvil, together with the spindle of the micrometer. The sleeve carries the graduations, which, in conjunction with the beveled and graduated part of the thimble, give the measure of the opening between the end faces of the anvil and the spindle. The ratchet arrangement provided at the end of the thimble prevents the spindle from pressing further against the surface of the piece being measured after the required feel has been attained, thus facilitating a uniform reading and preventing the instrument from being damaged. Lock nut or locking lever is used for locking the micrometer for a desired amount of time after taking or setting the reading. The construction of the outside micrometer is discussed as under.

COMMON PARTS OF OUTSIDE MICROMETER

(1) **Frame.** The U frame of micrometer is made of steel, cast steel, malleable cast iron or light alloy.

(2) **Hardened anvil.** It protrudes from the frame for a distance of at least 3 mm for holding and supporting the jobs for measurement.

(3) **Screwed spindle.** It does the actual measuring and possesses threads of 0.5 mm pitch.

(4) **Barrel or Sleeve.** It has datum or fiducially line and fixed graduations.

(5) **Thimble.** This is a tubular cover fastened with the spindle and moves with the spindle. The beveled edge of the thimble is divided into 50 equal parts, every fifth being numbered.

(6) **Ratchet.** This part is commonly recognized as friction stop of the micrometer, which acts as a precautionary measure also. It is a small extension to the thimble in which the ratchet slips when the pressure on the screw exceeds a certain amount. This produces uniform reading and prevents any damage or distortion of the instrument.

(7) **Spindle clamp.** It is used to lock the instrument at any desired setting or at any particular reading .

READING ON MICRO METER

It works on the fine assembly of nut and bolt principle where pitch of both nut and bolt plays a big role. The graduation on the barrel of micrometer is in two parts, namely one above the reference line and the other below. The higher line graduation above the reference line is graduated in 1 mm intervals. The first and every fifth are long and numbered 0, 5, 10, 15, 20 and 25. The lower or small graduations are graduated in mm intervals but each graduation shall be placed at the middle of the two successive upper graduations to be read 0.5 mm. The micrometer screw has a pitch of 0.5 mm, while the thimble has a scale of 50 divisions round its circumference. Thus, on making or rotating through one complete turn, the thimble moves forward or backward by one thread pitch of 0.5 mm, and one division of its scale is, therefore, equivalent to a longitudinal movement of $0.5 \times 1/50$ mm = 0.01 mm. It is the value of one division on the thimble, which is the least that can be correctly read with the help of a micrometer and is known as the least count. For measurement, the job is kept between the end of the spindle and the fixed anvil, which is fitted to the frame. When the micrometer is closed, the line marked 0 (zero) on the thimble coincides with the line marked 0 (zero) on the graduated sleeve. In metric outside micrometer, the pitch of the spindle screw is 0.5 mm

and the graduations provided on the spindle of the micrometer are in millimeters and subdivided into 0.5 mm. Now in one turn of the thimble of the micrometer, owing to the 0.5 mm. pitch of the spindle screw, the spindle will move through 0.5 mm and therefore, the corresponding opening between the faces of the fixed anvil and the spindle will be 0.5 mm. This opening will go on increasing by the same distance 0.5 mm for each further rotation of the thimble. The beveled edge of the thimble carries 50 equal divisions on its periphery in which every 5th division is marked. It is seen above that for one complete turn of the thimble the spindle moves through 0.5 mm. Now let the thimble is rotated one small division on its beveled edge i.e. 1/50 of the turn. The corresponding displacement of the spindle will then be $0.5 \times 1 / 50 = 0.01$mm.

Depth micrometer is used for measuring depth of holes and is shown in Fig. 19.13. Screw thread micrometer (Fig. 19.14) is used to measure the pitch diameter of the thread to an accuracy of 0.01mm and 0.001 inches. It comprises of similar parts as that of outside micrometer accept the shapes of fixed and moveable anvils. The fixed and moveable anvils possess the thread profiles for thread adjustment for measurement of the pitch diameter.

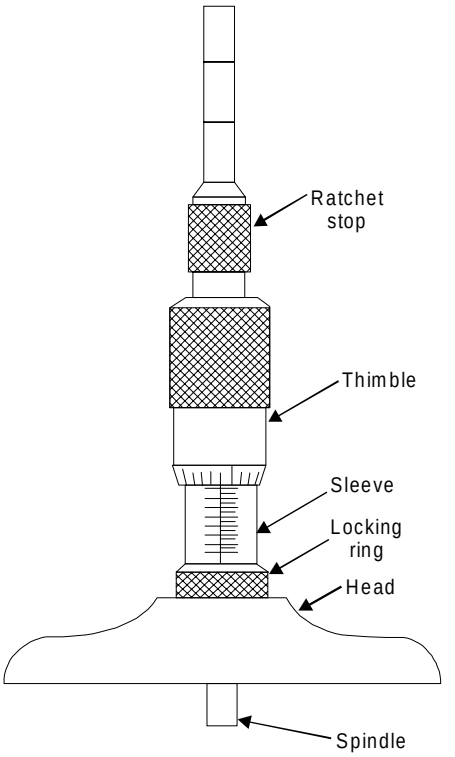


Fig. 9.13 A depth micrometer

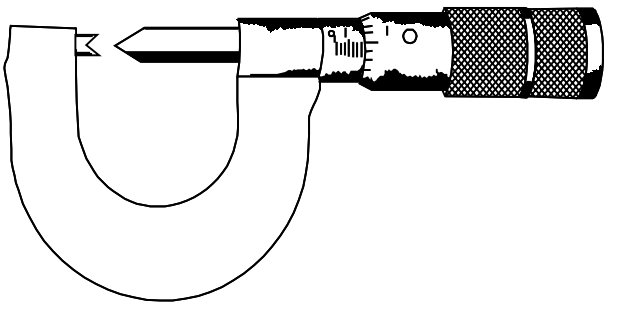


Fig. 9.14 A screw thread micrometer

19.2.3.2 Steel Rule

It is the simplest measuring tool just like a scale used in fitting shop. A six inch semi flexible rule is shown in Fig. 19.15 Other types of rules are described in the chapter on carpentry shop. Most of the dimensions are measured by the steel rule in workshops.

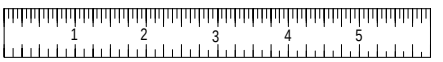


Fig. 9.15 A steel rule

19.2.3.3 Caliper

Calipers are generally of two types inside and outside to make internal or external measurements. They do not have direct scale reading. They transfer the measurement from jobs to scale or vice versa. Fig. 19.16 shows a simple outside caliper. The caliper is held in a rule as shown in Fig. 19.17 to read the size. It is used to make external measurement such as thickness of plates, diameter of sphere and cylinders. Fig. 19.18 shows the standard spring joint outside caliper.

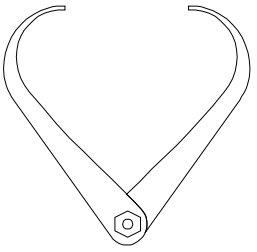


Fig. 9.16 A simple outside caliper

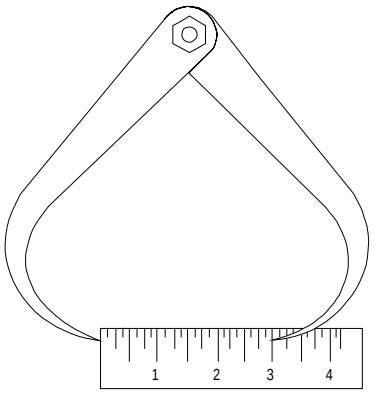


Fig. 9.17 A caliper held in rule

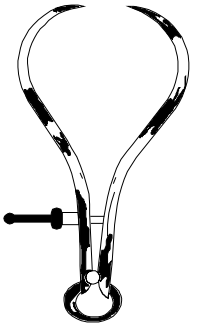


Fig. 9.18 A standard spring joint outside caliper

19.2.3.4 Vernier Caliper

Fig. 19.19 shows the vernier caliper, which is commonly used to measure accurately

(1) outside diameters of shafts,

(2) thicknesses of various parts,

(3) diameters of holes or rings and

(4) internal dimensions of hollow jobs or articles.

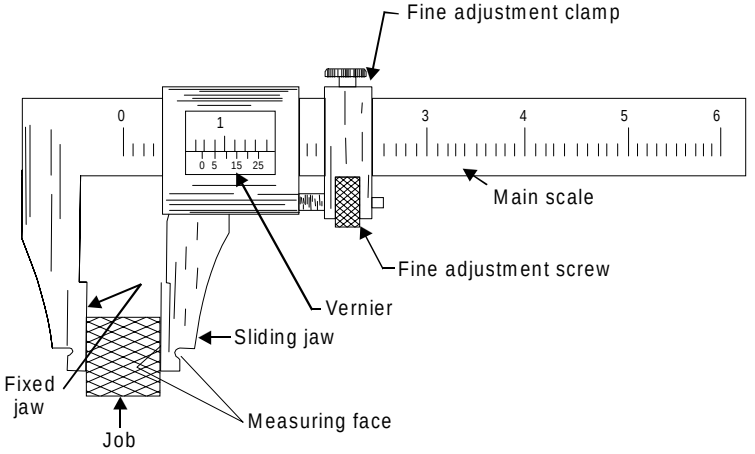


Fig. 19.19 A vernier caliper

It works on the principle of vernier and can measure the dimensions to an accuracy of 0.02 mm. For making a measurement of external dimensions, the job is placed between the

fixed and the movable jaws. The movable or the sliding jaw is moved until it almost contacts the job kept against the fixed jaw. The sliding jaw assembly of the vernier caliper that carries the fine adjustment screw should be clamped to the graduated beam with the help of adjustment clamp. The two jaws are then brought into contact with the job by moving the sliding jaw with the help of fine adjustment screw. The jaws should make now definite contact with the job but should not be tight. The main slide assembly is then locked to the beam with help of clamp. The caliper is then carefully removed from the job to prevent springing the jaws and the reading is taken. For making a measurement of internal dimensions, the job is placed outward between the fixed and the movable jaws meant for measuring inner dimension.

19.2.3.5 Vernier Depth Gauge

Vernier depth gauge is basically employed for checking depths of blind holes such as grooves, slots, depth of key ways and heights of shoulders, etc. The principle on which it works is the same as that of a vernier caliper. It is available with similar measuring accuracies as the vernier caliper and readings are taken the similar manner. It consists of a movable head with a base, which moves along the beam. A main scale on the beam and vernier scale on the sliding head with fine adjustment screw are incorporated in the similar manner as in a vernier caliper.

19.2.3.6 Vernier Height Gauge

Fig. 19.20 illustrates the vernier height gauge, which is employed for measuring the height of parts and in precision marking work. It consists of a heavy base, an accurately finished bottom, a vertical bar mounted square to the base, carrying the main scale, a sliding head with vernier, an auxiliary head with fine adjustment screw and nut and a bracket attached to the sliding head. This bracket is provided with a clamp by means of which interchangeable jaws can be fixed over there. The jaws can be fixed for measuring height or replaced by scribing jaws according to requirement or need. The graduations on the height gauge are given in Fig. 19.21.

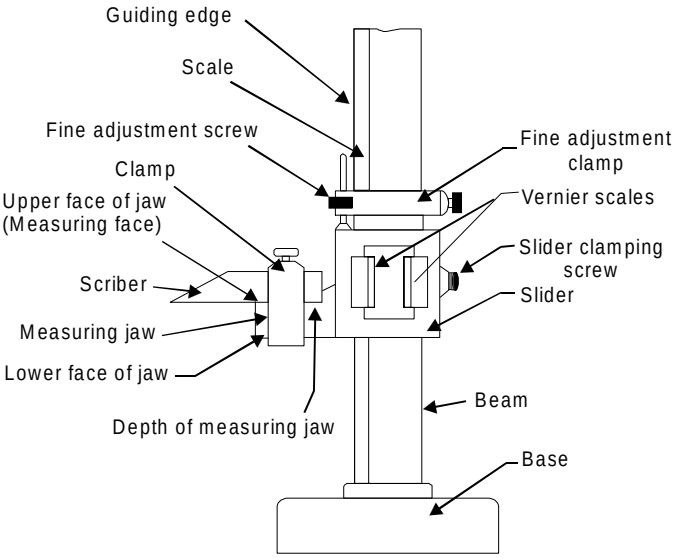


Fig. 19.20 A vernier height gauge

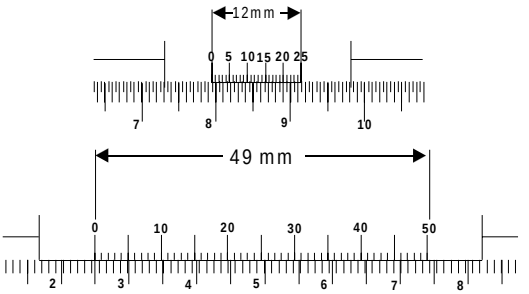


Fig. 19.21 A graduation on the vernier height gauge

19.2.3.7 Wire Guage

The wire gauge is a flat and circular steel sheet metal piece having slots all along its periphery as shown in Fig. 19.22. These slots have different standard sizes, which are engraved near their bottom. The size of each slot represents the correct diameter of the wire or thickness of the sheet of which it represents the gauge. The gauge number varies inversely as the size of the wire. That is the higher the gauge number, the thinner the wire and vice versa.

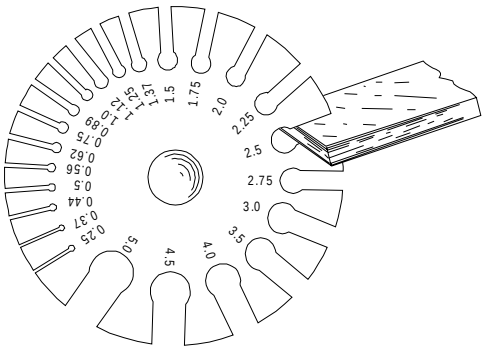


Fig. 19.22 A wire gauge

19.2.3.8 Dial Indicators

The dial indicators are also known as dial gauges and are shown in Fig. 19.23 (a, b). They are generally used for testing flatness of surfaces and parallelism of bars and rods. They are also used for testing the machine tools. They are available in both metric as well as in inches units. Inches dial indicator of 0.001" measuring accuracy is in commonly used but they are also available up to an accuracy of 0.0001". The commonly used metric dial indicator has an accuracy of 0.01 mm. Those having 0.001 mm accuracy are also available, however they are used in highly precision measurement work.

19.2.3.9 Bevel Gauge

An adjustable bevel gauge is widely used for checking, comparing or transferring angles and laying out work. It comprises of two adjustable blades, which can be positioned into almost any orientation to adjust any required angle. However, the direct reading is not obtained and the angle must be set or checked from some other angular measuring instrument.

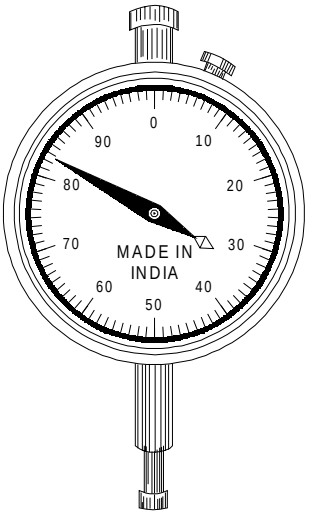


Fig. 19.23 (a) A continuous type dial indicator

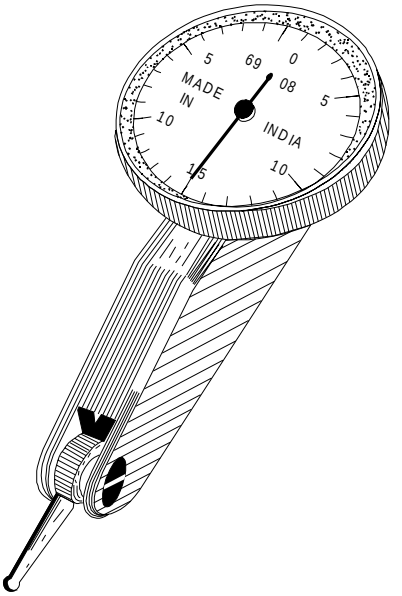


Fig. 19.23 (b) A dial indicator of Brown and Sharp Co.

19.2.3.10 Combination Set

Combination set is an important instrument which has the combination of instruments namely square head, a centre head, and a bevel protractor and sprit level as depicted in Fig. 19.24. It is a very useful instrument frequently utilized in the bench work and machine shop measurements. The three portions of the combination set are used separately being held in at any desired position by nuts which engage in a slot machined on the whole length of the beam at its back. The beam of the instrument acts as a rule, which is marked in inches or centimeters or in both for measuring the length and height as and when required. The square head possesses one edge square to the rule, giving a right angle, where as the other edge form an angle of 45°. It is provided with a spirit level. The scale on the protractor may be divided into degrees or a vernier attached whereby the angle can be measured in degrees and minutes. It is also fitted with a spirit level to help in leveling the work of setting it at an angle. The centre head with the rule fastened to it is called a centre square. It has two arms at right angles to one another and is so set on the rule that this angle is exactly divided in two by the edge of the rule. It may be used to find the centre of a round bar or shaft. Spirit level is commonly used for checking levels and other measurement. It is designed to handle measurements, layout and checking of angles. The square head is used for checking 90° angle or as a square as shown in Fig 19.25. The protractor head may be utilized with a rule to measure angles or to measure the slope of a surface as shown in Fig. 19.26.

19.2.3.11 Semi-circular Protractor

It resembles with a semi-circular protractor and is commonly used is geometrical drawings. Protractor used in sheet metal work is made from steel and often required for making or measuring angles.

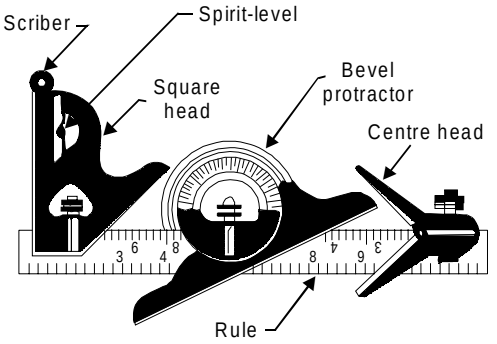


Fig. 19.24 A combination set

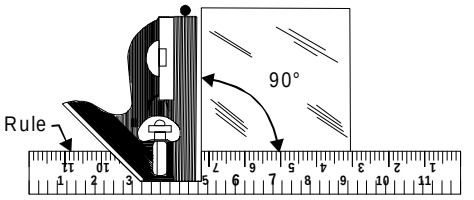


Fig. 19.25 Checking 90° angle using combination set

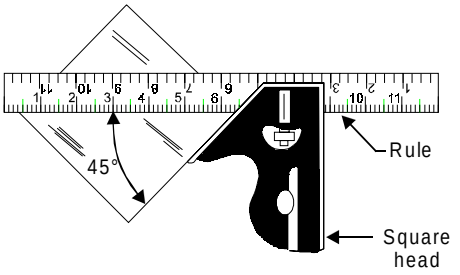


Fig. 19.26 Checking 45° angle using combination set

19.2.3.12 Slip Gauges

Slip gauges are also called as precision gauges blocks. They are made of rectangular blocks using alloy steel, which are being hardened before finishing them to size of high degree of accuracy. They are basically used for precise measurement for verifying measuring tools such as micrometers, comparators, and various limit gauges. The distance between two opposite faces determines the size of the gauge. They are made in higher grades of accuracy. The grade most commonly used in the production of components, tools, and gauges is Grade I, for rough work. Grade II and for checking other gauges. They are supplied in sets, the size of which varies from a set of about 112 pieces down to one containing 32 pieces. In English measurement there are five sets containing 81,49,41,35 and 28 pieces. An 81-set has a wide range of combination but for general purpose a 49-set is usually preferred. The measurement is made by end to end assembly of slip gauge blocks and very little pressure in wring form is being applied.

19.2.3.13 Inspection Gauges

Inspection gauges are commonly employed to avoid costly and lengthy process of testing the component dimensions. Fig. 19.27 represented the principle of limit gauging. These gauges are basically used for checking the size, shape and relative positions of various parts. These are of fixed type measuring devices and are classified as standard and limit. Standard gauges are made to the nominal size of the part to be tested and have the measuring member equal in size to the mean permissible dimension of the part to be checked. Limit gauges or "go" and "no go" gauges are made to the limit sizes of the job to be measured. Sides or ends of the gauge are made corresponding to maximum and minimum permissible size of the job for its acceptance or rejection. The objective of limit gauges is to identify whether the actual dimensions of the work are within or outside the specified limits of acceptance. The double

end kind of limit gauge has the GO portion at one end and the NO GO portion at the other end. GO portion must pass into or over an acceptable piece but the NO GO portion should not pass. Inspection gauges may be classified as working, inspection, and reference or master gauges. The working and inspection gauges are generally employed for inspection of components from stage to stage.

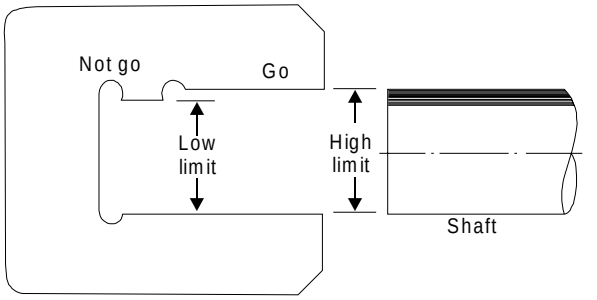


Fig. 19.27 A principle of limit gauge

Reference or master gauges are needed only for checking the size or condition of other gauges. The gauges are generally classified into:

1. Gauges for checking shafts
2. Gauges for checking holes
3. Gauges for checking forms
4. Gauges for checking threads
5. Gauges for checking tapers

The gauges commonly used in production work are

1. Progressive or step plug gauge (Fig. 19.28(a))
2. Thread plug gauge (Fig. 19.28(b))
3. A combination of internal and external non adjustable gauges (Fig. 19.28(c))

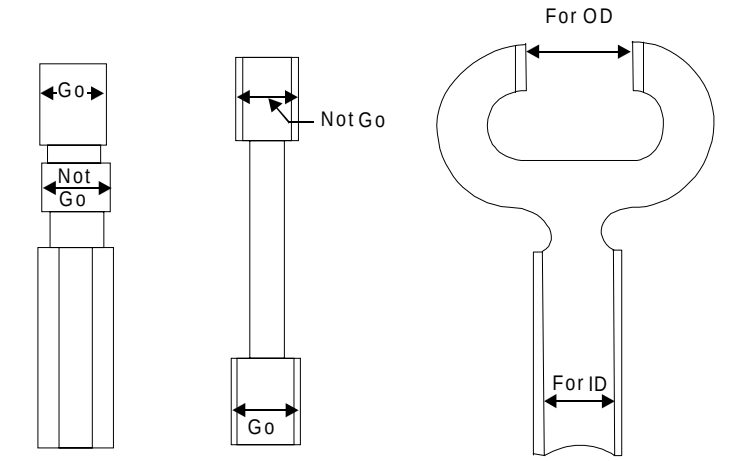


Fig. 19.28 Types of gauges

4. Ring gauge
5. Snap gauges (Fig. 19.29)

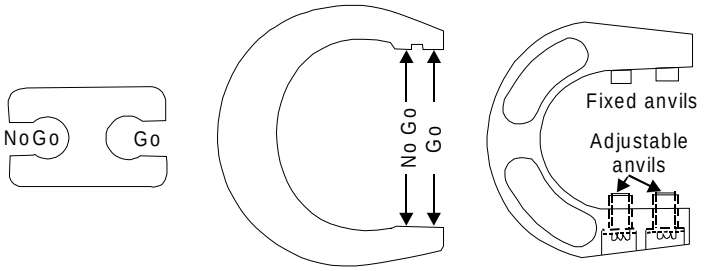


Fig. 19.29 Snap gauges

6. Feeler gauge (Fig. 19.30)

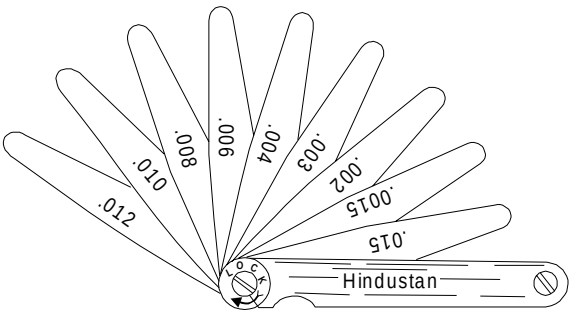


Fig. 19.30 A feeler gauge

7. Wire gauge
8. Template gauge
9. Adjustable gap gauge (Fig. 19.31)
10. Screw pitch gauge (Fig. 19.9)
11. Fillet and radius gauge

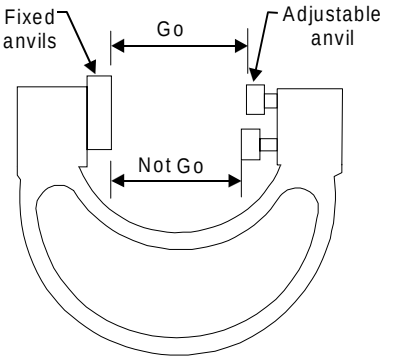


Fig. 19.31 An adjustable gap gauge

For manufacturing the above gauges, high carbon and alloy steels materials are commonly employed for manufacturing or production of gauges. Steel gauges may be used subject to some distortion during hardening. These difficulties can be overcome by making gauges by use of cemented carbide material or providing chrome plating at the surface of the gauge.

Plug Gauges

These are used for checking cylindrical, tapered, threaded, splined and square holes portions of manufacture components.

19.2.4 Holding Tools

Holding tools used in fitting shop comprises of basically vices and clamps. The clamps are C or G clamp, plane slot, goose neck, double end finger, u-clamp, parallel jaw, and clamping block. The various types of vices used in fitting shop are given as under:

19.2.4.1 Vices

The vices are hand vice, bench vice, machine vices, carpenter vice, shaper vice, leg vice, pipe vice, and pin vice.

19.2.4.1.1 Bench vice

Fig 19.32 shows a bench vice commonly used in fitting shop for holding a variety of jobs.

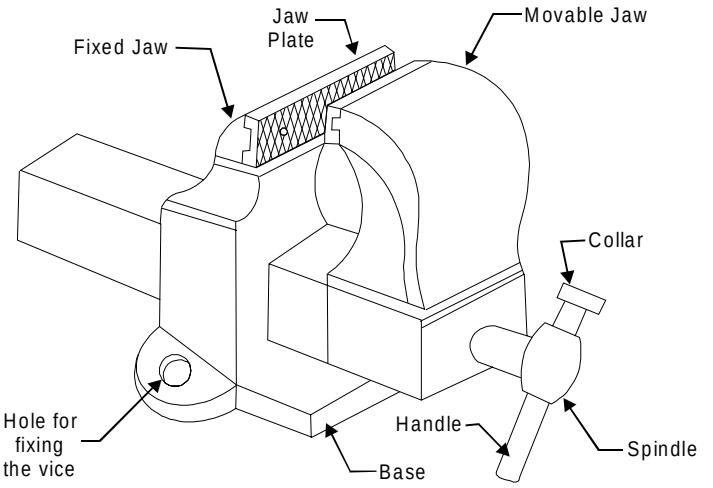


Fig. 19.32 A bench vice

19.2.4.1.2 Machine vice

Fig 19.33 and Fig. 19.34 shows machine vice with swivel base and parallel jaw machine vice. These types of vices are commonly used in fitting shop for holding a variety of jobs. They are used for precision work on the machine table like shaping, milling, drilling and grinding. They are generally made of grey cast iron.

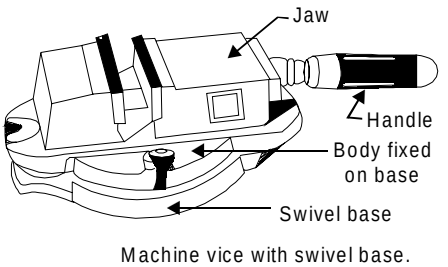


Fig. 19.33 A machine vice with swivel base

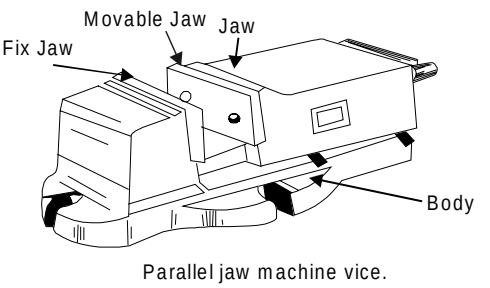


Fig. 19.34 A machine vice with parallel jaw

19.2.4.1.3 Universal swivel base machine vice

Fig. 19.35 shows a special type of universal swivel base machine vice made with swivelling head. It is commonly used in fitting shop for holding a variety of jobs. The jobs after holding in jaws can be adjusted at any angle either horizontally or vertically with the help of swelling head.

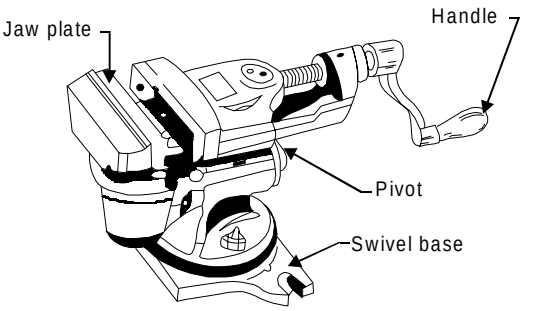


Fig. 19.35 A universal swivel base machine vice

19.2.4.1.4 Toolmaker's vice

Fig 19.36 shows a small tiny vice known as tool maker vice. It is commonly used by tool maker, watch maker, die maker and goldsmith for holding a variety of small parts for carrying some operation.

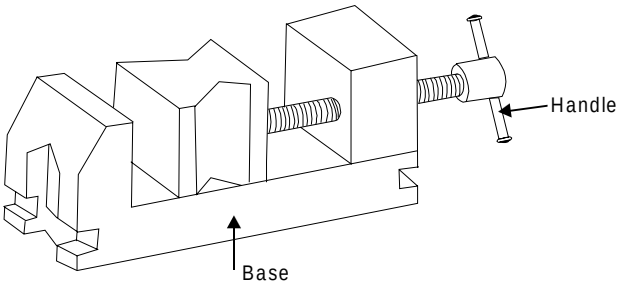


Fig. 19.36 A tool maker's vice

19.2.4.1.5 Hand vice

Hand vice is shown in Fig. 19.37 which is utilized for holding keys, small drills, screws, rivets, and other similar objects which are very small to be easily held in the bench vice. This is made in various shapes and sizes. It consists of two legs made of mild steel which hold the jaws at the top and are hinged together at the bottom. A flat spring held between the legs which tend to keep the jaws open. Its jaws can be opened and closed by a wing nut which moves through a screw that is fastened to one leg and passes through the other.

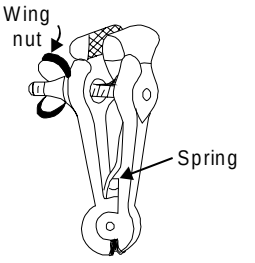


Fig. 19.37 Hand vice

19.2.4.1.6 Pin vice

Pin vice is used for holding round jobs of small diameter such as wire and pins, during working. It also forms a very useful handle for small files. It consists of a handle and a tapered nose covering a small collet chuck at its end. The chuck carries the jaws which are operated by turning the handle. It is commonly used by a watch maker.

19.2.4.2 Clamping Divices

There are two types of clamps namely C clamp and tool maker clamp. A C-clamp is shown in Fig. 19.38 which is used for gripping the work during construction or assembly work. Whereas tool maker clamp (Fig. 19.39) is used for gripping or holding smaller jobs.

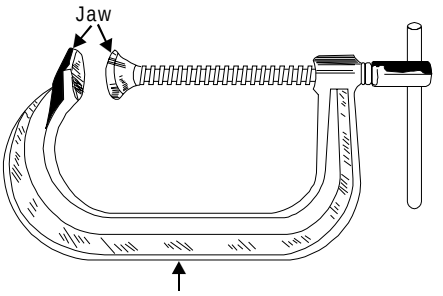


Fig. 19.38 C-clamp

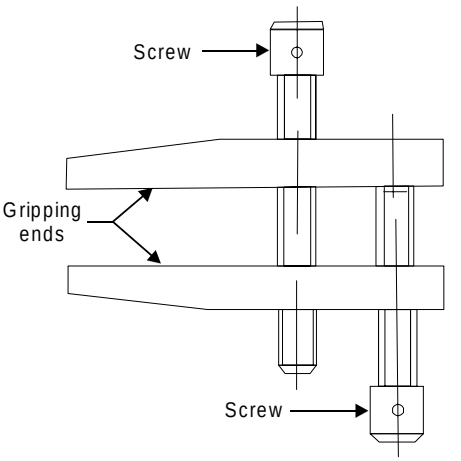


Fig. 19.39 A tool maker clamp

19.2.5 Cutting Tools

The important common cutting tools are discussed below

19.2.5.1 Files

The widely used hand cutting tool in workshops is the file. It is a hardened piece of high grade steel with slanting rows of teeth. It is used to cut, smooth, or fit metal parts. It is used file or cut softer metals. It consists of the following parts as shown in Fig. 19.40. The tang is the pointed part, which fitted into the handle. The point is the end opposite the tang. The heel is next to the handle. The safe edge or side of a file is that which has no teeth. It is classified on bases of type or cut of teeth and sectional form.

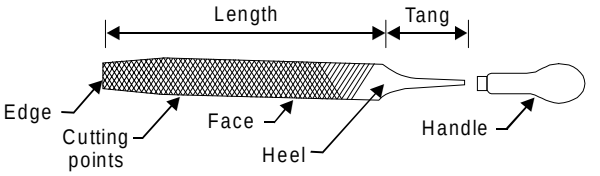


Fig. 19.40 Parts of a file

19.2.5.1.1 Size of a File

Size of a file is specified by its length. It is the distance from the point to the heel, without the tang. Files for fine work are usually from 100 to 200 mm and those for heavier work from 200 to 450 mm in length.

19.2.5.1.2 Classification of Files

The files are classified on basis of type of cuts, grade and shapes. These are further sub classified as under

(A) Type of Cut

The most commonly used files according to cuts of teeth are shown in Fig.19.41.

(*i*) Single

(*ii*) Double and

(*iii*) Rasp

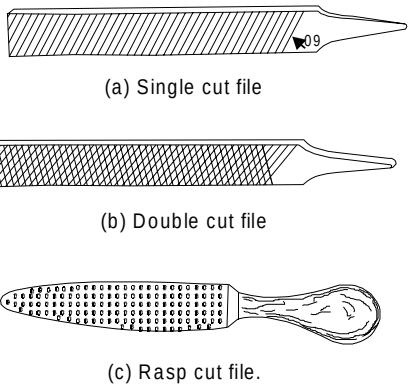


Fig. 19.41 Types of files according to cuts of teeth

(B) Grade of Cut

Files are cut with teeth of different grades. Those in general are

(*i*) Smooth

(*ii*) Second cut

(*iii*) Bastered

(*iv*) Rough

(C) Shape of File

Common shapes of files are having different cross sections, which cover most requirements.

19.2.5.1.3 Cut or teeth on files

Teeth or cuts of files can be categorized into two groups namely single cut and double cut. In single cut files, the teeth are cut parallel to other across the file at an angle of about 60° to the centre line of the file. Such types of file are named as flats and are widely used on hard metal.

A double-cut file possesses two sets of teeth, the over-cut teeth being cut at about 60° and the up cut at 75 to 80° to the centre line.

Single-cut and double-cut files are further classified according to the coarseness or spacing between the rows of the teeth. In descending order of roughness, such files are listed as:

(*i*) Smooth

(*ii*) Dead smooth

(*iii*) Rough

(*iv*) Bastard

(*v*) Second cut

(*vi*) Super smooth

These files are used for finishing general surface work. Both faces of file are double cut and both edges are single cut. Such files are commonly tapered in width and thickness.

General classification of files based on shapes or cross sections are shown in Fig. 19.42 along with their uses are as under:

19.2.5.1.4 Hand files

Hand files are commonly used for finishing surface work. Both faces of the file are double cut. Either both edges are single cut or one is uncut to provide a safe edge.

19.2.5.1.5 Flat files

Flat files are generally used for filing flat surfaces in fitting shop.

19.2.5.1.6 Triangular files

Triangular files are commonly used for filing corners between 60° and 90°. They are double cut on all faces.

19.2.5.1.7 Square files

Square files are commonly used for filing in corners in jobs. They are double cut on all sides and tapers.

19.2.5.1.8 Round files

Round files are generally used for opening out holes and rounding inside corners. Rough, bastard, second cut and smooth files under 15 cm in length are single cut.

19.2.5.1.9 Half round files

These files comprises of flat and half round sides. The flat side of half round file is used for general work and the half round side for filing concave surfaces. These files are double cut on the flat side. The curved side is single cut, smooth or second cut.

19.2.5.1.10 Knife-edge files

These files are commonly used for cleaning out acute-angled corners. The two faces of these files are double cut, while the edge is single cut. These files are made in sizes from 10 to 20 cm of various shapes and cuts. They are extremely delicate and are used for fine work such as pierced designed in thin metal.

19.2.5.1.11 Pillar files

These files are used for finishing narrow slots. Both faces are double cut and either both edges are single cut or one is uncut to provide a safe edge of the file.

19.2.5.1.12 Needle files

Needle files are generally used for filling keys tooth wheels of clocks and other curved surfaces.

19.2.5.1.13 Mill files

Mill files are commonly used for filing half round recess and gullet of mill saw.

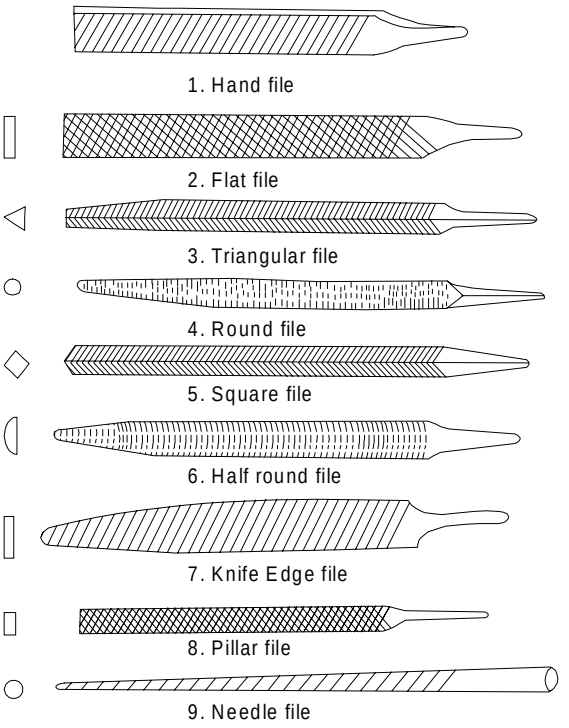


Fig. 19.42 General classification of files based on shapes or cross sections

19.2.5.2 Scrapers

Scrapers are made up of old files and the cutting edge of scraper is hardened and tempered. They are mainly used to scrap metal surfaces by rubbing the work surface. They also produce a bearing surface, which has been filed or machined earlier. The scrapers are hand cutting tools used for removing metal from surfaces in form of thin slices or flakes to produce smooth and fine surfaces. Machined surfaces are not always perfectly true. If a very true surface is needed, the high spots must be located and removed. It is normally done with the help of a scraper. The scrapers are made in a variety of lengths from 100 mm upwards and in many shapes, depending upon the type of work to be done. The following types of scrappers according to shape are commonly classified as

(*i*) Flat
(*ii*) Hook
(*iii*) Triangular
(*iv*) Half round

Fig 19.43 shows various scraper which are generally used for scraping job work in fitting shop. These are discussed as under.

19.2.5.2.1 Flat scrapers

Flat scrapers are commonly used for removing slight irregularities on a flat surface.

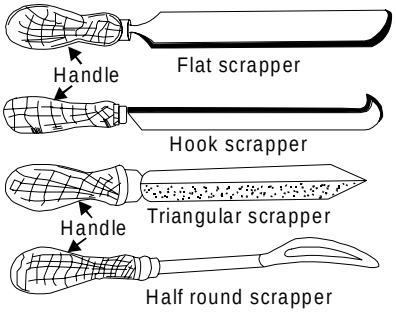


Fig. 19.43 Common types of scraper

When the surface has been scraped with strokes in one direction, it must then be scraped with strokes at 90° to the first ones.

19.2.5.2.2 Hook scrapers

Hook scrapers are widely used for scraping minor job work in fitting shop.

19.2.5.2.3 Triangular scrapers

These are generally used to finish bearings in the same way as the half round scrapers, but since they come to a sharp point at the tip they removes burrs at the edge of small holes which a half round scraper could not enter. The faces of the scraper are hollow ground to give the tool three cutting edges which are simpler to sharpen than the edges of the half round scraper.

19.2.5.2.4 Half-round scrapers

These types of scrapers are widely used for scraping internal cylindrical surfaces. They are used to remove high spots in bore & and bearings to give the right type of fit to the mating shaft or journal.

Scrapers are stored carefully for protection of cutting edges from damage.

19.2.5.3 Chisel

Chisel is one of the most important tools of the sheet metal, fitting and forging shop. It is widely used for cutting and chipping the work piece. It is made of high carbon steel or tool steel. It is in the form of a rod having cutting edge at one end, hexagonal or octagonal body and striking head at the other end. The size of a chisel is described by its length and width of edge. When the cutting edge becomes blunt, it is again sharpened by grinding. For cutting the job or work piece with the chisel, it is placed vertically on the job or work piece and hammering is carried out upon its head. But for chipping, the chisel is inclined at 40°-70° with the job orwork piece. The angle of the cutting edge of the chisel is 35°-70°according to the metals to be cut.

19.2.5.4 Drill

Drill is a common tool widely for making holes in a metal piece in fitting shop. It is generally held in chuck of bench drilling machine shown in Fig. 19.44. It usually consists of two cutting edges set at an angle with the axis. There are three types of drills: (*a*) flat drill, (*b*) straight fluted drill and (*c*) twist drill. For fast and accurate drilling work twist drills are commonly used. A general twist drill comprises the cutting angle of 118° and to obtain the correct diameter of the hole. It should be ground with both lips at 59° to the axis of the drill, with equal lengths of the cutting edges. The various hand drills and their operations are shown in Fig. 19.45.

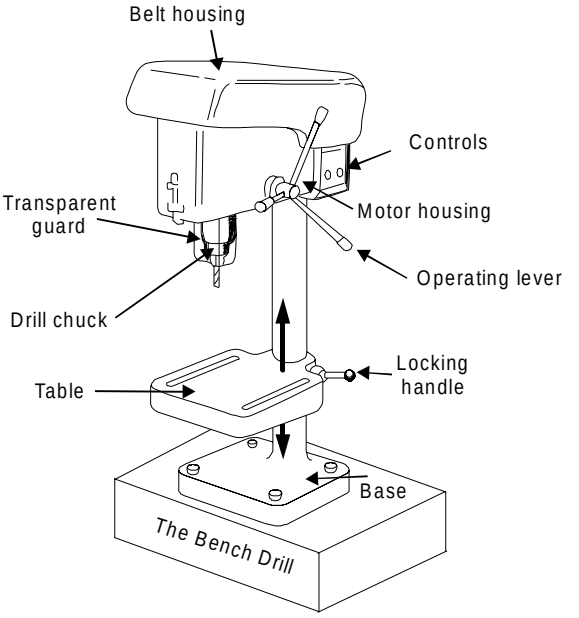


Fig. 19.44 A bench drilling machine

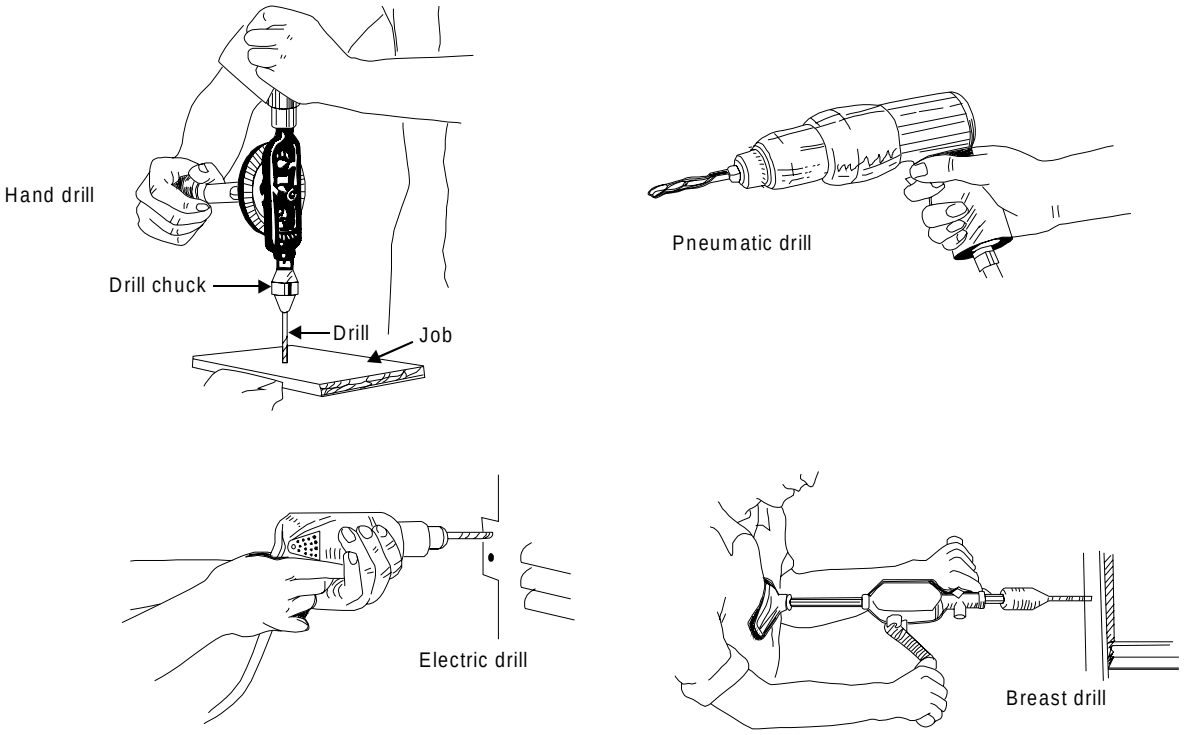


Fig. 19.45 Types of hand drilling machine

19.2.5.5 Reamer

The drill does not always produce the correct hole some time with good finish. Thus a correct hole is produced with good finish of a pre drilled hole using a reamer. A common hand reamer is shown in Fig. 19.46. It is commonly employed to remove minimum amount of metal (100 to 150 micron for rough reaming and 5 to 20 micron for fine reaming) from the hole. During reaming operations, the job should be properly supported and rigidly held. A stock wrench of appropriate size for holding the reamer is used. The reamer must be kept in its correct position relative to the job. It must be run slowly and excessive feed must be avoided. It should be always be turned in the cutting direction. Sufficient amount of cutting fluid should also be employed. When removing the reamer, it must be turned in the cutting direction. Reamers with blunt or chipped edges must not be used.

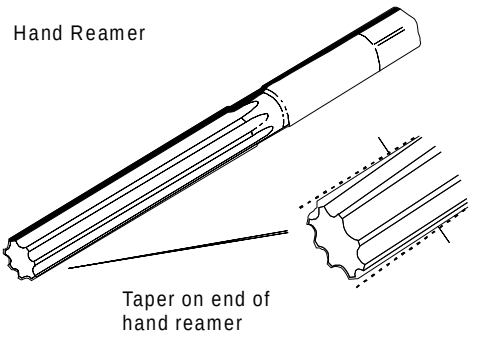


Fig. 19.46 A common hand reamer

19.2.5.5.1 Types of reamers

The reamers are classified as under.

(*i*) Hand reamer
(*ii*) Machine reamers
(*iii*) Parallel reamer
(*iv*) Taper reamer
(*v*) Reamers with straight flutes
(*vi*) Reamers with spiral flutes
(*vii*) Adjustable reamer
(*viii*) Expanding reamer

Some common types of reamer generally used in fitting shops are discussed as under.

19.2.5.5.1.1 Hand reamer

Hand reamer is operated or rotated by hand to finish holes and remove its ovality. Its cutting edges are backed off in the same manner as those of twist drills to give suitable clearance. It is made up of carbon or high speed steel. It is used for very fine internal turning in the hole by placing a tap wrench on the squared end of the reamer.

19.2.5.5.1.2 Machine reamer

Machine reamer is designed for slow speeds for use on drill presses, lathes, vertical milling machines etc. It is chamfered on the front side of cutting edge. It possesses straight or tapered shanks and comprises of either straight or spiral flutes.

19.2.5.5.1.3 Taper reamer

Taper reamer is widely used for finishing taper holes smoothly and accurately. It is also used to provide a taper to a drilled hole when a taper pin is to be used. It is generally performed with either straight or spiral flutes. It has spaces ground into the cutting edges or teeth to prevent overloading the entire length of each tooth of the reamer. These spaces are staggered on the various teeth to help in stock removal. The spiral fluted reamer has a shearing action that eliminates chatter and is generally preferred. Large size taper reamers are made in both roughing and finishing types. When a large amount of stock is to be removed, a roughing reamer is generally used. The finishing reamer is commonly employed to control size and smooth the hole.

19.2.5.5.1.4 Spiral fluted reamer

Spiral fluted reamer performs greater shearing action than one with straight flute.

19.2.5.6 TAPS

Taps are used for cutting or producing internal threads of either left or right hand kind in nuts or pre-drilled holes. Taps are threaded externally. The threads being cut by grinding to give a high class finish. Taps are made up of alloy steel or hardened steel. To provide cutting edges, grooves known as flutes are ground along the threaded portion of the tap so that the thread is divided into rows of teeth. The number of flutes on tap varies from two to eight whereas four being the most common. The flutes acts as channels to carry away the chips formed during tapping or cutting threads. The nomenclature of a typical tap is shown

in Fig. 19.47. Taps are may be of many types such as hand taps, machine taps, pipe taps, solid taps, straight and bend shank taps. Hand taps are usually made in sets of three: (1) taper tap (2) plug tap (3) bottoming tap as shown in Fig. 19.48. The taper tap is tapered off for 8 or 10 threads, and is used first, cutting to the full thread gradually. The intermediate tap usually has two or three threads chamfered. The second tap can finish a through hole. The plug tap has a full-sized un-tapered thread to the end and is the main finishing tap. In the case of blind hole, a plug tap must be used.

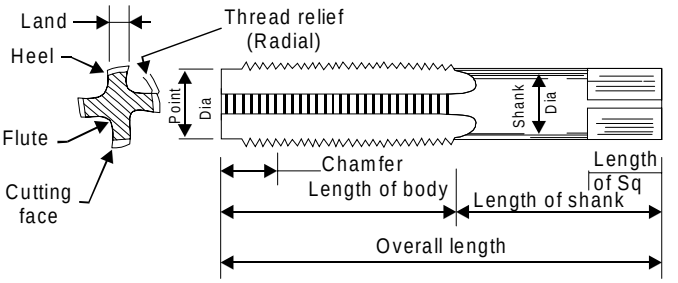


Fig. 19.47 Nomenclature of tap

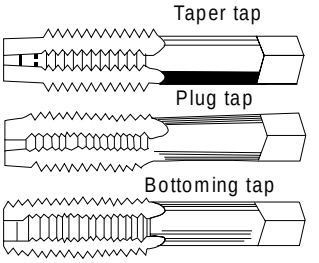


Fig. 19.48 Types of hand taps

19.2.5.7 Hand snip or shear

Various kinds of snips or shears are described in chapter pertaining to sheet metal work. They are commonly employed for cutting or shearing metal sheets to required shapes and sizes. Few snips are available for making straight or circular cuts. The most common types of snips in use are:

(*a*) Straight snips,

(*b*) Bent snips and

(*c*) Slitting shears

19.2.5.8 Hand hacksaw

Hand hacksaws are made in two types namely a fixed frame and adjustable frame oriented as shown in Fig.19.49 and Fig.19.50. The former possesses solid frame in which the length cannot be changed and where as the latter comprises the adjustable frame which has a back that can be lengthened or shortened to hold blades of different sizes. The hand hacksaws are commonly used for sawing all soft metal. They consist of a frame, handle, prongs, tightening screw and nut, and blade as shown in figure. Its frame is made to hold the blade tightly. However a power operated hacksaw can also be used for cutting raw materials in sizes in case of continuous cutting generally occurring frequently in fitting or in machine shops.

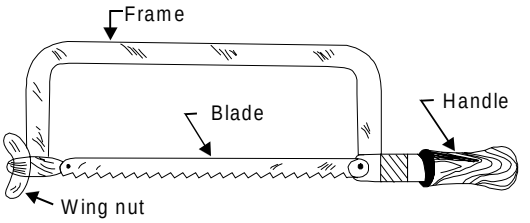


Fig. 19.49 A fixed frame hacksaw

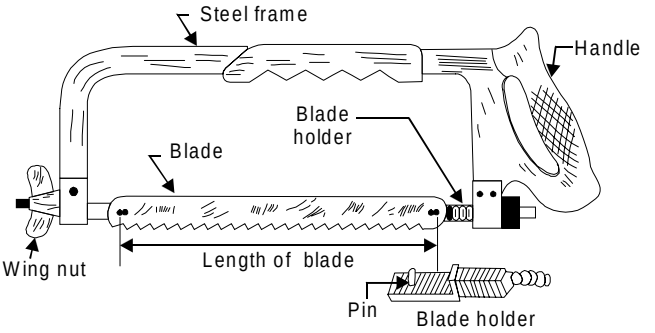


Fig. 19.50 An adjustable frame hacksaw

19.2.6 Sriking Tools

Various types of hammers (such as ball peen hammer, straight peen hammer, cross-peen hammer, double face hammer and soft face hammer) are acting as striking tools. These types have been described in chapters relating to sheet metal work and forging work. The common type of ball peen hammer and their parts are shown in Fig. 19.51.

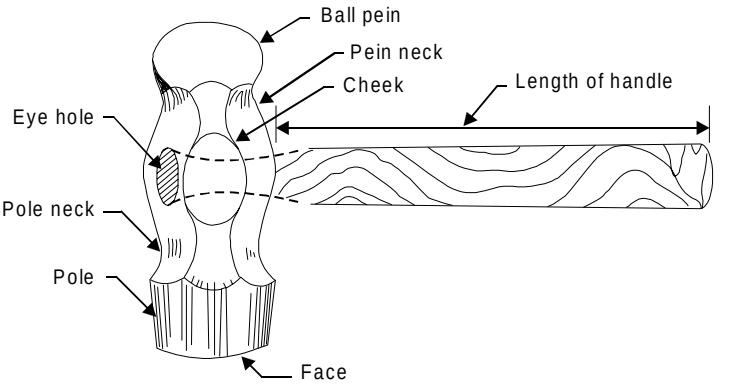


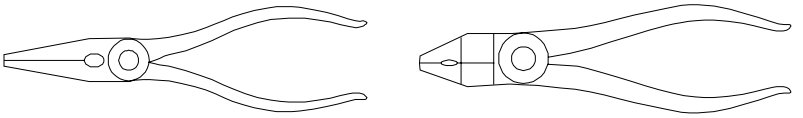
Fig. 19.51 Common type of ball peen hammer and their parts

19.2.7 Tightening Tools

The tightening tools include pliers, screw driver and wrenches, which are discussed as under.

19.2.7.1 Pliers

Pliers are namely ordinary needle nose and special type. Fig 19.52(a) shows a long nose pliers and Fig. 19.52(b) shows a combination pliers. These are commonly used by fitter and electrician for holding a variety of jobs.



(a) Long nose pliers. (b) Combination pliers.

Fig. 19.52 Long nose pliers and combination pliers

19.2.7.2 Screw driver

Screw driver is a screw tightening tool. The most commonly used standard screw driver with its parts is shown in Fig 19.53. It is generally used by hand for tightening the screws. It is also of various types depending upon the kind of work.

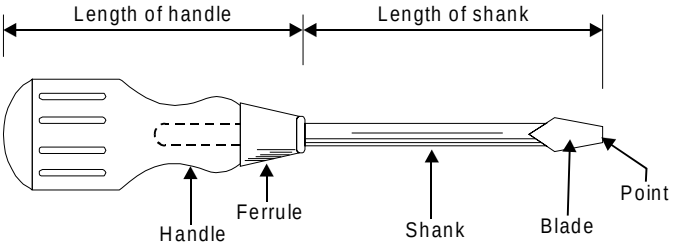


Fig. 19.53 Standard screw driver with its parts

19.2.7.3 Wrenches

Wrenches are commonly known as spanners. These generally come in sets and are commonly identified by numbers. These are of various types and few general types involve open single ended, open double ended, closed ended adjustable, ring spanner, offset socket, t-socket, box wrench, pipe wrench and Allen wrench.

19.3 OPERATIONS PERFORMED IN FITTING WORK

The operations commonly performed in bench and fitting work may be classified as under.

1. Marking
2. Chipping
3. Filing
4. Scrapping
5. Sawing
6. Drilling
7. Reaming
8. Tapping
9. Grinding and
10. Polishing

Some common operations are discussed as under.

19.3.1 Grinding

Grinding is generally called as fine machining or finishing operations of removing materials from surface usually 0.25-0.50 mm in most operations through the use of grinding wheel. Grinding wheel is highly useful in removing extra unwanted metal and sharpening cutting tools such as chisels, drill, taps, and other cutting tools. It may be used to finish almost all surface, which has been previously roughly shaped by some other processes or to remove the extra material which is too hard to be removed by other machining processes. The accuracy in fine grinding is in few microns or even less. In grinding, the work is held pressed against the high speed rotating grinding wheel and the metal gets reduced by abrasion. Grinding wheel is generally made from silicon carbide or aluminium oxide. It is generally made up of particles of hard substance called the abrasive and is embedded in a matrix called the bond. These abrasives form the cutting points in a wheel and are termed as grains. The abrasives are of generally two types namely natural and artificial. Emery and corundum are two natural abrasives, while carborundum and aloxite are artificial abrasives. The hardness or softness of the wheel is dependent on the amount and kind of the bonding material. Generally, hard wheels of aloxite are used for grinding soft materials and soft wheels of carborundum for grinding hard materials using various types of grinding machines known as grinders. In wet grinding, large amount of coolant over the work and on wheel face is provided. Coolant will remove heat generated during grinding and promotes long wheel life and produces very good surface finish. The cutting face of a grinding wheel should be kept in a true, clean and sharp conditioned shape for obtaining efficient cutting. Suitable dressers are also employed periodically for reconditioning and dressing of glazed or blunt wheels. Grinder may be various types such as cylindrical grinder, surface grinder, pedestal grinder, tool and cutter grinder, centre-less grinder, internal grinder and jig grinder and profile grinder. Fig. 19.54 illustrates the surface grinding machine and principle of surface grinding. Fig. 19.55 illustrates the principle of cylindrical grinding.

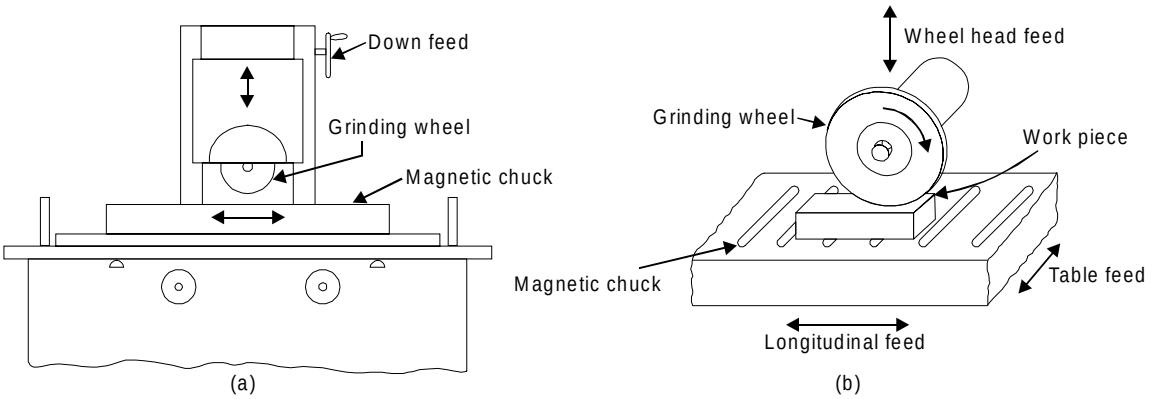


Fig. 19.54 Surface grinding machine and its principle

19.3.2 Polishing

Polishing is surfacing finishing process for producing a flat, scratch-free, mirror-like finish. It consists of fine grinding, intermediate grinding, rough polishing, and fine polishing. Initially the surface to be polished is roughly ground to remove deep cut off marks. Then the intermediate grinding is done with fine emery or silicon carbide (Carborundum) papers decreasing in grit size in three to four stages to remove grinding marks. Emery papers are

graded from fine to coarse. This polishing operation may be performed by hand or mechanically using the rotating disks. The motion in polishing of work on polishing wheel should always be straight and the polishing strokes should cover the whole length of the surface being polished. Finer grade emery disc pr polishing wheel should be used for the fine finish work. Polishing is commonly performed on utensils.

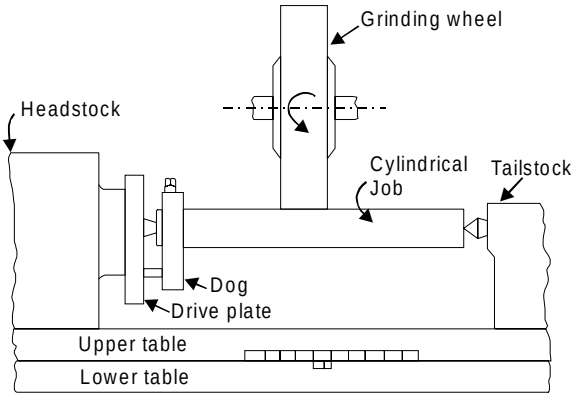


Fig. 19.55 Principle of cylindrical grinding

19.3.3 Surface Coating

The various manufacturing processes such as casting, forging, machining, hot working, cold working and joining processes etc. produce different surfaces. Therefore for getting desired surface of the part, subsequent surface preservation processes are needed. These preservation processes are called as surface coating of metals. Coatings on surfaces are employed on most metal parts, either for protective or for decorative or for both purposes. The main objectives of coatings involve for the purpose of decoration, surface protection, corrosion resistance and providing of a hard surface. The surface covering with coating must be uniform and free from runs, checks or peelings. Coatings are commonly applied to the finished components to form the final product. For successful coating, clean and smooth surface finishes is required for assuring good adhesion during coating. Cleaning operations are performed both preparatory to finishing operations and after finishing operations. They are primarily used to remove dirt, oil, oxides, scale, and other harmful ingredients that ultimately affect the life of the product. There are various methods of cleaning, drying, and competitive means of applying the coating. However, the various processes involved in preparing work for coating and applying the coatings are closely interrelated. Galvanizing, parkerizing, electroplating and painting are the common surface coating processes employed for protecting the surfaces of the work pieces.

19.4 QUESTIONS

1. How will you classify the tools commonly used in fitting ?
2. Explain briefly the various clamping tools used in fitting shop using neat sketches.
3. Explain in brief with neat sketches the various types of measuring tools used in fitting shop.
4. Explain the construction and working of vernier caliper using neat sketch. How its least count can be determined? What are its uses?

5. Explain the construction and working of micrometer with neat sketches. How its least count can be determined?
6. Explain in brief the various types of cutting tools used in fitting shop using neat sketches.
7. Explain in brief the various precautions associated with hand hacksaw, files and chisels.
8. Explain in brief the various types of striking tools used in fitting shop using neat sketches.
9. Explain the various types of files used in fitting shop. How are they classified ?
10. Explain the following tools.
    (*i*) Drill (*ii*) Reamer
    (*iii*) Taps (*iv*) Die and die stock
11. Write short notes on the following operations:
    (*i*) Marking (*ii*) Filing (*iii*) Chipping
    (*iv*) Sawing (*v*) Drilling (*vi*) Tapping
    (*vii*) Grinding (*viii*) Polishing (*ix*) Punching
12. What is the main difference between the hand hammers used in a smithy shop and a fitting shop?
13. What is the difference between hand hacksaw used in fitting shop and the saws used in carpentry shop?
14. Write short notes on the following:
    (*i*) Polishing (*ii*) Buffing (*iii*) Boring
    (*iv*) Milling (*v*) Broaching (*vi*) Shaping
    (*vii*) Grinding.
15. How will you achieve the following?
    (*i*) Rate of production (*ii*) Accuracy and
    (*iii*) Surface finish

20
CHAPTER

METAL CUTTING

20.1 INTRODUCTION

Metal cutting or traditional machining processes are also known as conventional machining processes. These processes are commonly carried out in machine shops or tool room for machining a cylindrical or flat jobs to a desired shape, size and finish on a rough block of job material with the help of a wedge shaped tool. The cutting tool is constrained to move relative to the job in such a way that a layer of metal is removed in the form of a chip. General metal cutting operations are shown in Fig. 20.1. These machining processes are performed on metal cutting machines, more commonly termed as machine tools using various types of cutting tools (single or multi-point). A machine tool is a power driven metal cutting machine which assist in managing the needed relative motion between cutting tool and the job that changes the size and shape of the job material. In metal cutting (machining) process, working motion is imparted to the workpiece and cutting tool by the mechanisms of machine tool so that the work and tool travel relative to each other and machine the workpiece material in the form of shavings (or swarf) known as chips.

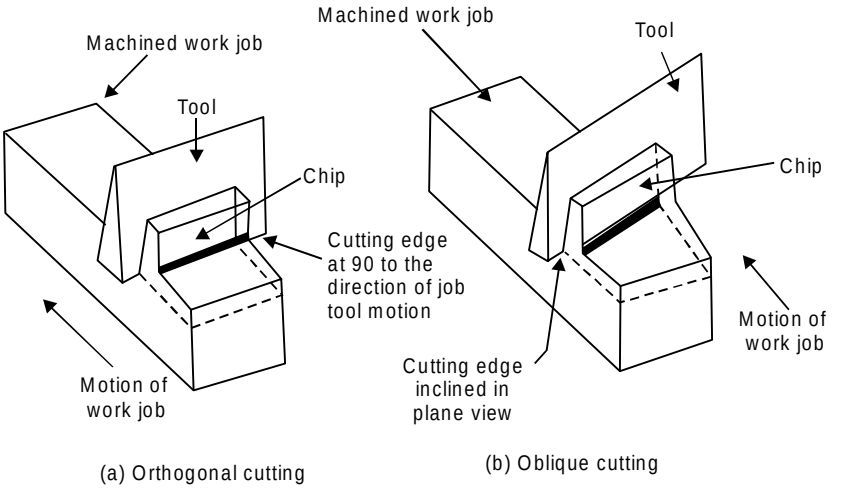


Fig. 20.1 Metal cutting operation

The machine tools involve various kinds of machines tools commonly named as lathe, shaper, planer, slotter, drilling, milling and grinding machines etc. The machining jobs are mainly of two types namely cylindrical and flats or prismatic. Cylindrical jobs are generally machined using lathe, milling, drilling and cylindrical grinding whereas prismatic jobs are machined using shaper, planner, milling, drilling and surface grinding.

In metal cutting operation, the position of cutting edge of the cutting tool is important based on which the cutting operation is classified as orthogonal cutting and oblique cutting. Orthogonal cutting (Fig. 20.2) is also known as two dimensional metal cutting in which the cutting edge is normal to the work piece. In orthogonal cutting no force exists in direction perpendicular to relative motion between tool and work piece. Oblique cutting (Fig. 20.3) is the common type of three dimensional cutting used in various metal cutting operations in which the cutting action is inclined with the job by a certain angle called the inclination angle.

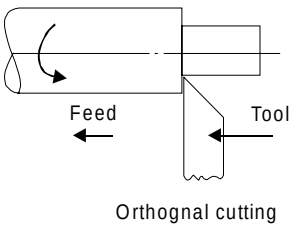


Fig. 20.2 Orthogonal cutting

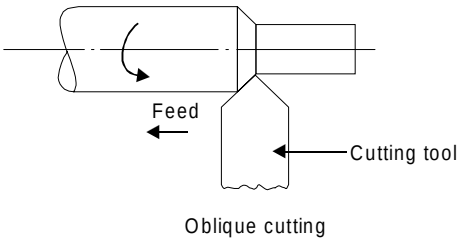


Fig. 20.3 Oblique cutting

20.2 CUTTING TOOL

Cutting tools performs the main machining operation. They comprise of single point cutting tool or multipoint cutting tools. It is a body having teeth or cutting edges on it. A single point cutting tool (such as a lathe, shaper and planner and boring tool) has only one cutting edge, whereas a multi-point cutting tool (such as milling cutter, milling cutter, drill, reamer and broach) has a number of teeth or cutting edges on its periphery.

20.2.1 Single Point Cutting Tools

There are mainly two types of single point tools namely the solid type as shown in Fig.20.4 and the tipped tool (Fig.20.5). The solid type single point tool may be made from high speed steel, from a cast alloy. Brazed tools (Fig.20.6) are generally known as tool bits and are used in tool holders. The tipped type of tool is made from a good shank steel on which is mounted a tip of cutting tool material. Tip may be made of high speed steel or cemented carbide. In addition to this, there are long index-able insert tools and throwaway. The Insert type tool throwaway refers to the cutting tool insert which is mechanically held in the tool holder. The inserts are purchased which are ready for use. When all cutting edges are used, the insert is discarded and not re-sharpened. These tools can be further classified depending upon the operations for which they are used and the type of the shank (straight or bent shank type). Tools may be of the types planning tools, turning tools, facing tool, boring tools, parting and slotting tools etc.

Different types of carbide tips are generally used on tipped tool. In general the straight shank type tools are cheaper to manufacture as compared to bent shank type. But bent shank type can be used for turning either longitudinal or cross feed without resetting and for

turning, facing and chamfering operations. Boring tools usually quite long and the cross-section is small.

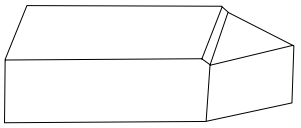


Fig. 20.4 Solid type of single point cutting tool

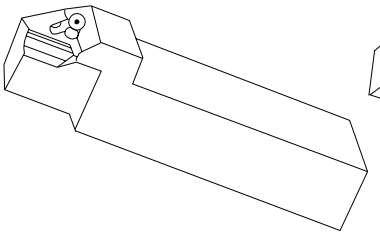


Fig. 20.5 Tipped type single point cutting tool

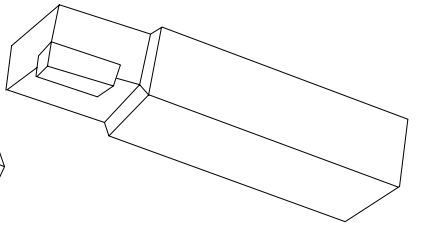


Fig. 20.6 Index-able insert type single point cutting tool

A single point cutting tool can be understood by its geometry (Fig.20.7). Geometry comprises mainly of nose, rake face of the tool, flank, heel and shank etc. The nose is shaped as conical with different angles. The angles are specified in a perfect sequence as American Society of Tool Manufacturer for recognizing them as under.

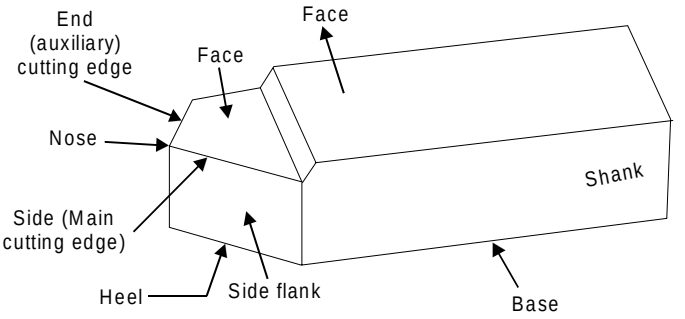


Fig. 20.7 Geometry of single point cutting tool

20.2.2 Nomenclature Single Point Tool

The elements of tool signature or nomenclature single point tool is illustrated in Fig. 20.8

(*i*) Back rake angle

It is the angle between the face of the tool and a line parallel with base of the tool measured in a perpendicular plane through the side cutting edge. If the slope face is downward toward the nose, it is negative back rake angle and if it is upward toward nose, it is positive back rake angle. This angle helps in removing the chips away from the work piece.

(*ii*) Side rake angle

It is the angle by which the face of tool is inclined side ways. This angle of tool determines the thickness of the tool behind the cutting edge. It is provided on tool to provide clearance between work piece and tool so as to prevent the rubbing of work- piece with end flake of tool. It is the angle between the surface the flank immediately below the point and the line down from the point perpendicular to the base.

(*iii*) End relief angle

It is the angle that allows the tool to cut without rubbing on the work- piece. It is defined as the angle between the portion of the end flank immediately below the cutting edge and a line perpendicular to the base of the tool, measured at right angles to the flank. Some time extra end clearance is also provided on the tool that is also known as end clearance angle. It is the secondary angle directly below the end relief angle

(*iv*) Side relief angle

It is the angle that prevents the interference as the tool enters the material. It is the angle between the portion of the side flank immediately below the side edge and a line perpendicular to the base of the tool measured at right angles to the side. It is incorporated on the tool to provide relief between its flank and the work piece surface. Some time extra side clearance is also provided on the tool that is also known as side clearance angle. It is the secondary angle directly below the side relief angle.

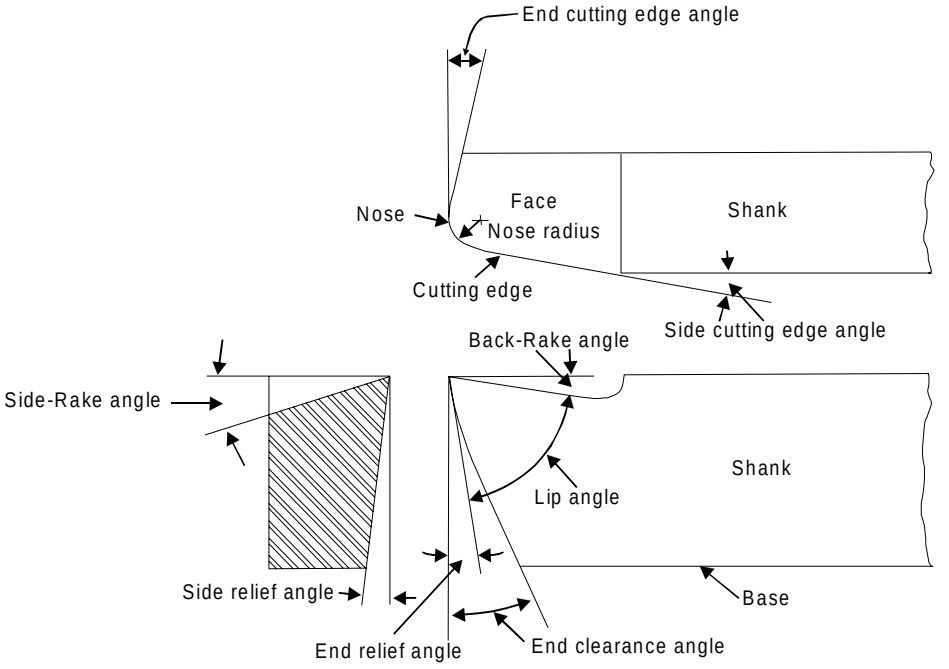


Fig. 20.8 Elements of tool signature or nomenclature of single point tool

(*v*) End cutting edge angle

It is the angle between the end cutting edge and a line perpendicular to the shank of the tool. It provides clearance between tool cutting edge and work piece.

(*vi*) Side cutting edge angle

It is the angle between straight cutting edge on the side of tool and the side of the shank. It is also known as lead angle. It is responsible for turning the chip away from the finished surface.

(*vii*) Nose radius

It is the nose point connecting the side cutting edge and end cutting edge. It possesses small radius which is responsible for generating surface finish on the work-piece

20.2.3 Tool Signature

Convenient way to specify tool angles by use of a standardized abbreviated system is known as tool signature or tool nomenclature. It indicates the angles that a tool utilizes during the cut. It specifies the active angles of the tool normal to the cutting edge. This will always be true as long as the tool shank is mounted at right angles to the work-piece axis. The seven elements that comprise the signature of a single point cutting tool can be stated in the following order:

Tool signature 0-7-6-8-15-16-0.8

1. Back rake angle (0°)
2. Side rake angle (7°)
3. End relief angle (6°)
4. Side relief angle (8°)
5. End cutting edge angle (15°)
6. Side cutting edge angle (16°)
7. Nose radius (0.8 mm)

20.3 MECHANICS OF METAL CUTTING

Metal cutting operation is illustrated in Fig. 20.9. The work piece is securely clamped in a machine tool vice or clamps or chuck or collet. A wedge shape tool is set to a certain depth of cut and is forced to move in direction as shown in figure. All traditional machining processes require a cutting tool having a basic wedge shape at the cutting edge. The tool will cut or shear off the metal, provided (*i*) the tool is harder than the metal, (*ii*) the tool is properly shaped so that its edge can be effective in cutting the metal, (*iii*) the tool is strong enough to resist cutting pressures but keen enough to sever the metal, and (*iv*) provided there is movement of tool relative to the material or vice versa, so as to make cutting action possible. Most metal cutting is done by high speed steel tools or carbide tools. In metal cutting, the tool does not slide through metal as a jack knife does through wood, not does the tool split the metal as an axe does a log. Actually, the metal is forced off the workpiece by being compressed, shearing off, and sliding along the face of the cutting tool. The way a cutting tool cuts the metal can be explained as follows. All metals in the solid state have a characteristic crystalline structure, frequently referred to as grain structure. The grain or crystals vary in size from very fine to very coarse, depending upon the type of metal and its heat-treatment. The cutting tool advances again in the work piece. Heavy forces are exerted on the crystals in front of the tool face. These crystals, in turn exert similar pressures on crystals ahead of them, in the direction of the cut or force applied by the cutter. As the tool continues to advance, the material at sheared point is sheared by the cutting edge of the tool or it may be torn loose by the action of the bending chip which is being formed. As the tool advances, maximum stress is exerted along sheared line, which is called the shear plane. This plane is approximately perpendicular to the cutting face of the tool. There exists a shear zone on both sides of the shear plane, when the force of the tool exceeds the strength of the

material at the shear plane, rupture or slippage of the crystalline grain structure occurs, thus forming the metal chip. The chip gets separated from the workpiece material and moves up along the tool face. In addition, when the metal is sheared, the crystals are elongated, the direction of elongation being different from that of shear. The circles which represent the crystals in the uncut metal get elongated into ellipses after leaving the shearing plane.

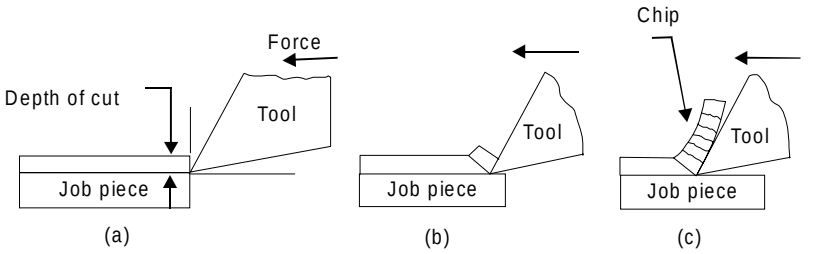


Fig. 20.9 Metal cutting operation

20.4 TYPES OF CHIPS

In a metal cutting operation is carried out in machine shop. Chips are separated from the workpiece to impart the required size and shape to the workpiece. The type of chips edge formed is basically a function of the work material and cutting conditions. The chips that are formed during metal cutting operations can be classified into four types:

1. Discontinuous or segmental chips
2. Continuous chips
3. Continuous chips with built-up edge.
4. Non homogenous chips

The above three common types of chips are shown in Fig. 20.10

Fig. 20.10 (a) shows continuous chips coming out during machining in machine shop. These types of chips are obtained while machining ductile material such as mild steel and copper. A continuous chip comes from the cutting edge of a cutting tool as a single one piece, and it will remain as one piece unless purposely broken for safety or for convenience in handling. Formation of very lengthy chip is hazardous to the machining process and the machine operators. It may wrap up on the cutting tool, work piece and interrupt in the cutting operation. Thus, it becomes necessary to deform or break long continuous chips into small pieces. It is done by using chip breakers. Chip breaker can be an integral part of the tool design or a separate device.

Fig. 20.10 (b) shows discontinuous chips coming out during machining in machine shop. In this type, the chip is produced in the form of small pieces. These types of chips are obtained while machining brittle material like cast iron, brass and bronze. Fairly good surface finish is obtained and tool life is increased with this type of chips.

Fig. 20.10 (c) shows continuous chip with built-up edge. During cutting operation, the temperature rises and as the hot chip passes over s the face of the tool, alloying and welding action may take place due to high pressure, which results in the formation of weak bonds in microstructure and weakened particles might pullout. Owing to high heat and pressure generated, these particles get welded to the cutting tip of the tool and form a false cutting edge. This is known as built-up edge

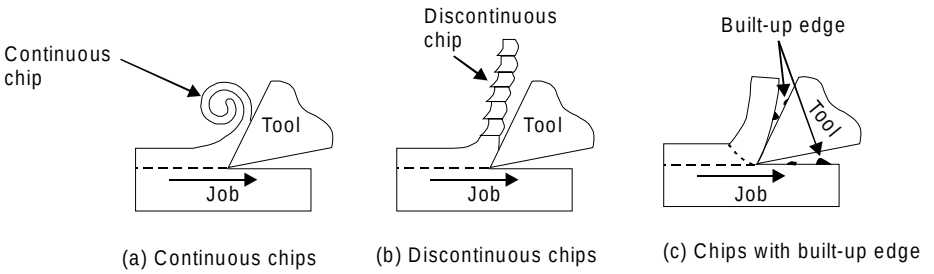


Fig. 20.10 Common types of chips

Non homogenous chips are developed during machining highly hard alloys like titanium which suffers a marked decrease in yield strength with increase in temperature

20.5 COOLENTS OR CUTTING FLUIDS OR EMULSIONS

During any machining or metal cutting process, enough heat is evolved in cutting zone. To remove this heat from cutting zone, soluble oils are used as cutting fluid during machining. Emulsions (also known as soluble oil) cool the work-piece and tool and thus relieved them from overheat. Air circulation is required so as to remove the heat by evaporation. The remaining oil forms a protecting layer over the machined work piece and save it from rust and corrosion. Such coolants decrease adhesion between chip and tool, provides lower friction and wear and a smaller built up edge. They remove chips and hence help in keeping freshly machined surface bright. They also protect the surface from corrosion. They decrease wear and tear of tool and hence increase tool life. They improve machinability and reduce machining forces. Chemical cutting fluids possess a good flushing action and are non-corrosive and non-clogging. Since they are non-clogging, they are widely used for grinding and sawing. The most efficient method of applying cutting fluids is to use a pump, tray and reservoir, to give a slow continuous stream over the cutting action. Chemical cutting fluids are replacing straight and emulsifiable cutting oils for many applications. If chemical concentrates are mixed in correct proportion with deionized water, chemical cutting fluids provide longer life at less cost than oil base cutting fluids. Other coolants and cutting fluids are cutting wax and kerosene.

Cutting fluids may also be used on aluminium, aluminium alloys and brass for machining operations of low severity. It may be used as a coolant and for removing chips when machining cast iron. Some commonly used machining materials require following cutting fluids:

Steel	Soluble oil	Straight,	Water base mainly grinding
Aluminium and alloys	Paraffin	Dry	
Cast iron	Dry		
Brass, Copper and Bronze	Dry		

20.5.1 Functions or Uses of Collents or Cutting Fluids

The important functions of cutting fluids are given as under.

(*i*) Cutting fluid washes away the chips and hence keeps the cutting region free.

(*ii*) It helps in keeping freshly machined surface bright by giving a protective coating against atmospheric, oxygen and thus protects the finished surface from corrosion.

(*iii*) It decreases wear and tear of cutting tool and hence increases tool life.

(*iv*) It improves machinability and reduce power requirements

(*v*) It prevents expansion of work pieces.

(*vi*) It cools the tool and work piece and remove the generated heat from the cutting zone.

(*vii*) It decreases adhesion between chip and tool; provide lower friction and wear, and a smaller built-up edge.

20.6 NON TRADITIONAL OR UNCONVENTIONAL MACHINING PROCESSES

Non traditional machining processes are also known as un-conventional metal machining or advance machining processes. The recent increase in the use of hard, high strength and temperature resistant materials in engineering has necessitated the development of newer machining techniques. With the exception of grinding, conventional methods of removing material from a workpiece are not readily applicable to these new materials. New materials such as hastalloy, nitralloy, waspalloy, nimonics, carbides etc., are difficult to machine and which possess tremendous applications in aircrafts, nuclear reactors, turbines, special cutting tools etc. Conventional machining processes when applied to these harder materials have following difficulties which are given as under.

(*i*) Conventional machining processes are uneconomical to these material,

(*ii*) Produce poor degree of accuracy and surface finish,

(*iii*) Produce some stress in the metal being cut whereas newer machining techniques are essentially stress free.

(*iv*) Theses processes are slow and highly insufficient.

Although most of the new machining processes have been developed specifically for newer materials that are difficult to machine, some of them (processes) have found use in the production of complex shapes and cavities in softer, more readily machined materials.

20.6.1 CLassification of Unconventional Machining Processes

Non-traditional or unconventional machining processes may be classified on the basis of the nature of energy employed in machining,

1. Chemical

1. Chemical machining (CHM)

2. Electro-chemical

1. Electro-chemical machining (ECM)
2. Electrolytic grinding (ECG)

3. Electro-thermal

1. Electrical discharge machining (EDM)
2. Electron beam machining (EBM)
3. Plasma arc machining (PAM)
4. Laser beam machining (LBM)

4. Mechanical

1. Ultrasonic machining (USM)
2. Abrasive jet machining (AJM)
3. Water jet machining (WJM)

20.7 QUESTIONS

1. Show the nomenclature of a single point cutting tool using orthographic projections.
2. Show nomenclature of the following cutting tools:
   (*i*) Single point cutting tool
   (*ii*) Drill
   (*iii*) Milling cutter
3. Explain orthogonal cutting and oblique cutting
4. Explain mechanism of chip formation with neat sketches.
5. Explain various types of chips with neat sketches.
6. What are objectives of cutting fluids?
7. Explain the mechanisms of tool wear. What are its regions?
8. What are the various costs associated with machining operation.
9. For a given set of conditions, how would you arrive at the best cutting speed for maximum production?
10. Describe the various types of chips in metal cutting.
    1. What is a chip breaker
    2. Orthogonal cutting
    3. Oblique cutting
    4. Friction of chip and tool.
    5. Heat generated and dissipated in metal cutting?
11. Describe power hacksaw with neat sketch.
12. What safety precautions are associated with operation of a power hacksaw machine?
13. Explain various safety precautions are to be considered while working in machine shop.

21
CHAPTER

LATHE MACHINE

21.1 INTRODUNCTION

Lathe is one of the most versatile and widely used machine tools all over the world. It is commonly known as the mother of all other machine tool. The main function of a lathe is to remove metal from a job to give it the required shape and size. The job is secure1y and rigid1y held in the chuck or in between centers on the lathe machine and then turn it against a single point cutting tool which wi1l remove meta1 from the job in the form of chips. Fig. 21.1 shows the working principle of lathe. An engine lathe is the most basic and simplest form of the lathe. It derives its name from the early lathes, which obtained their power from engines. Besides the simple turning operation as described above, lathe can be used to carry out other operations also, such as drilling, reaming, boring, taper turning, knurling, screw-thread cutting, grinding etc.

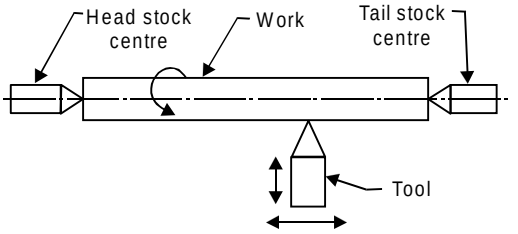


Fig. 21.1 Working principal of lathe machine

21.2 TYPES OF LATHE

Lathes are manufactured in a variety of types and sizes, from very small bench lathes used for precision work to huge lathes used for turning large steel shafts. But the principle of operation and function of all types of lathes is same. The different types of lathes are:

1. Speed lathe
   (*a*) Wood working
   (*b*) Spinning
   (*c*) Centering
   (*d*) Po1ishing

2. Centre or engine lathe
   (*a*) Be1t drive
   (*b*) Individual motor drive
   (*c*) Gear head lathe
3. Bench lathe
4. Tool room Lathe
5. Capstan and Turret 1athe
6. Special purpose lathe
   (*a*) Whee1 lathe
   (*b*) Gap bed lathe
   (*c*) Dup1icating lathe
   (*d*) T-lathe
7. Automatic lathe

Some of common lathes are described as under.

21.2.1 Speed Lathe

Speed lathe is simplest of all types of lathes in construction and operation. The important parts of speed lathe are following-

(1) Bed
(2) Headstock
(3) Tailstock, and
(4) Tool post mounted on an adjustable slide.

It has no feed box, 1eadscrew or conventional type of carriage. The tool is mounted on the adjustable slide and is fed into the work by hand contro1. The speed lathe finds applications where cutting force is least such as in wood working, spinning, centering, polishing, winding, buffing etc. This lathe has been so named because of the very high speed of the headstock spindle.

21.2.2 Centre Lathe or Engine Lathe

The term "engine" is associated with this lathe due to the fact that in the very early days of its development it was driven by steam engine. This lathe is the important member of the lathe family and is the most widely used. Similar to the speed lathe, the engine lathe has all the basic parts, e.g., bed, headstock, and tailstock. But its headstock is much more robust in construction and contains additional mechanism for driving the lathe spindle at multiple speeds. An engine lathe is shown in Fig. 21.2. Unlike the speed lathe, the engine lathe can feed the cutting tool both in cross and longitudinal direction with reference to the lathe axis with the help of a carriage, feed rod and lead screw. Centre lathes or engine lathes are classified according to methods of transmitting power to the machine. The power may be transmitted by means of belt, electric motor or through gears.

22.2.3 Bench Lathe

This is a small lathe usually mounted on a bench. It has practically all the parts of an engine lathe or speed lathe and it performs almost all the operations. This is used for small and precision work.

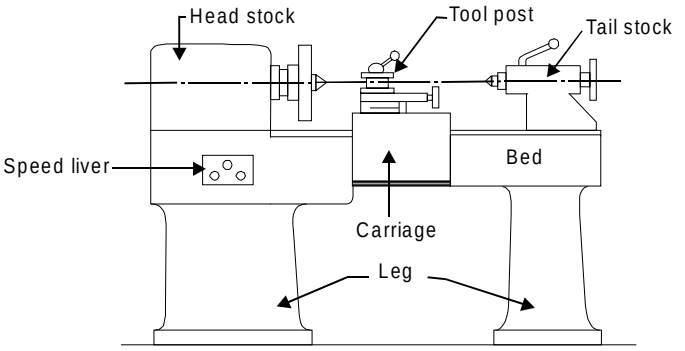


Fig. 21.2 Principal components of a central lathe

22.2.4 Tool Room Lathe

This lathe has features similar to an engine lathe but it is much more accurately built. It has a wide range of spindle speeds ranging from a very low to a quite high speed up to 2500 rpm. This lathe is mainly used for precision work on tools, dies, gauges and in machining work where accuracy is needed.

22.2.5 Capstan and Turret Lathe

The development of these 1athes results from the technological advancement of the engine lathe and these are vastly used for mass production work. The distinguishing feature of this type of lathe is that the tailstock of an engine lathe is replaced by a hexagonal turret, on the face of which multiple tools may be fitted and fed into the work in proper sequence. Due to this arrangement, several different types of operations can be done on a job without re-setting of work or tools, and a number of identical parts can be produced in the minimum time.

21.2.6 Special Purpose Lathes

These lathes are constructed for special purposes and for jobs, which cannot be accommodated or conveniently machined on a standard lathe. The wheel lathe is made for finishing the journals and turning the tread on railroad car and locomotive wheels. The gap bed lathe, in which a section of the bed adjacent to the headstock is removable, is used to swing extra-large-diameter pieces. The T-lathe is used for machining of rotors for jet engines. The bed of this lathe has T-shape. Duplicating lathe is one for duplicating the shape of a flat or round template on to the job.

21.2.7 Automatic Lathes

These lathes are so designed that all the working and job handling movements of the complete manufacturing process for a job are done automatically. These are high speed, heavy duty, mass production lathes with complete automatic control.

21.3 CONSTRUCTION OF LATHE MACHINE

A simple lathe comprises of a bed made of grey cast iron on which headstock, tailstock, carriage and other components of lathe are mounted. Fig. 21.3 shows the different parts of engine lathe or central lathe. The major parts of lathe machine are given as under:

1. Bed
2. Head stock
3. Tailstock
4. Carriage
5. Feed mechanism
6. Thread cutting mechanism

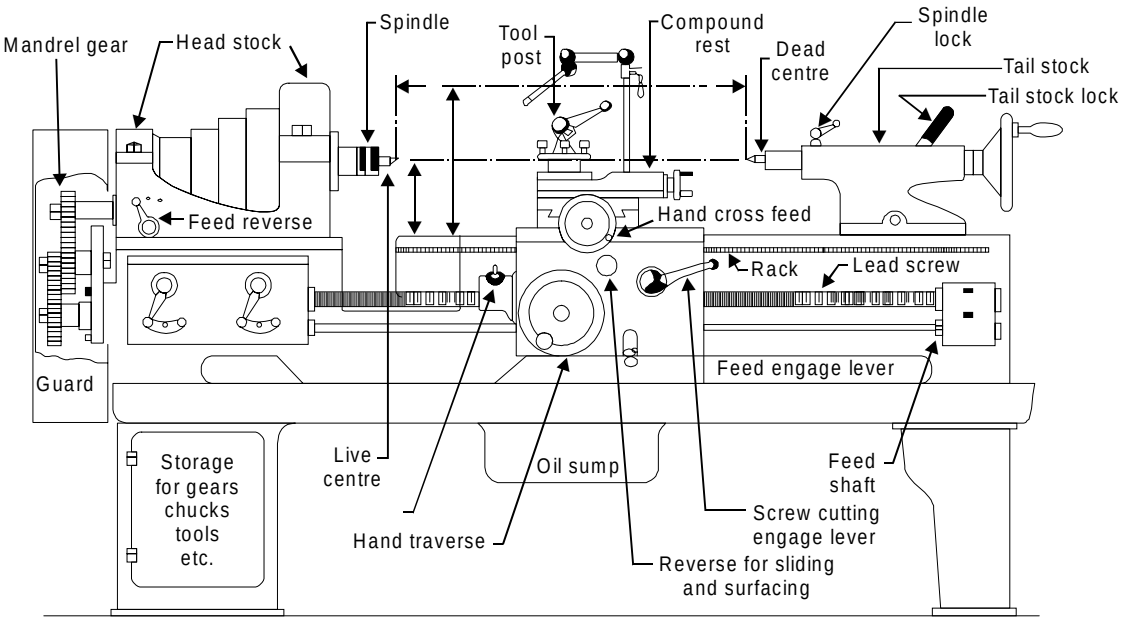


Fig. 21.3 Different parts of engine lathe or central lathe

21.3.1 Bed

The bed of a lathe machine is the base on which all other parts of lathe are mounted. It is massive and rigid single piece casting made to support other active parts of lathe. On left end of the bed, headstock of lathe machine is located while on right side tailstock is located. The carriage of the machine rests over the bed and slides on it. On the top of the bed there are two sets of guideways-innerways and outerways. The innerways provide sliding surfaces for the tailstock and the outerways for the carriage. The guideways of the lathe bed may be flat and inverted V shape. Generally cast iron alloyed with nickel and chromium material is used for manufacturing of the lathe bed.

21.3.2 Head Stock

The main function of headstock is to transmit power to the different parts of a lathe. It comprises of the headstock casting to accommodate all the parts within it including gear train arrangement. The main spindle is adjusted in it, which possesses live centre to which the work can be attached. It supports the work and revolves with the work, fitted into the main spindle of the headstock. The cone pulley is also attached with this arrangement, which is used to get various spindle speed through electric motor. The back gear arrangement is used

for obtaining a wide range of slower speeds. Some gears called change wheels are used to produce different velocity ratio required for thread cutting.

21.3.3 Tail Stock

Fig. 21.4 shows the tail stock of central lathe, which is commonly used for the objective of primarily giving an outer bearing and support the circular job being turned on centers. Tail stock can be easily set or adjusted for alignment or non-alignment with respect to the spindle centre and carries a centre called dead centre for supporting one end of the work. Both live and dead centers have 60° conical points to fit centre holes in the circular job, the other end tapering to allow for good fitting into the spindles. The dead centre can be mounted in ball bearing so that it rotates with the job avoiding friction of the job with dead centre as it important to hold heavy jobs.

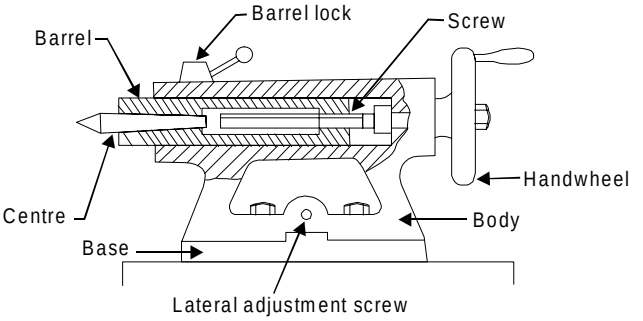


Fig. 21.4 Tail stock of central lathe.

21.3.4 Carriage

Carriage is mounted on the outer guide ways of lathe bed and it can move in a direction parallel to the spindle axis. It comprises of important parts such as apron, cross-slide, saddle, compound rest, and tool post. The lower part of the carriage is termed the apron in which there are gears to constitute apron mechanism for adjusting the direction of the feed using clutch mechanism and the split half nut for automatic feed. The cross-slide is basically mounted on the carriage, which generally travels at right angles to the spindle axis. On the cross-slide, a saddle is mounted in which the compound rest is adjusted which can rotate and fix to any desired angle. The compound rest slide is actuated by a screw, which rotates in a nut fixed to the saddle.

The tool post is an important part of carriage, which fits in a tee-slot in the compound rest and holds the tool holder in place by the tool post screw. Fig. 21.5 shows the tool post of centre lathe.

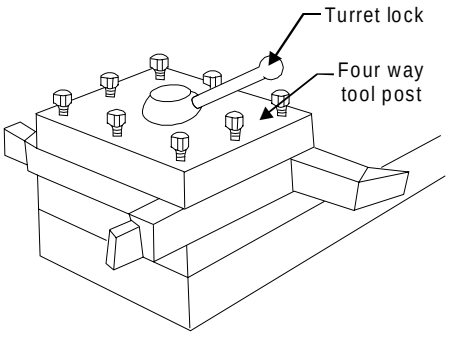


Fig. 21.5 Tool post of centre lathe

21.3.5 Feed Mechanism

Feed mechanism is the combination of different units through which motion of headstock spindle is transmitted to the carriage of lathe machine. Following units play role in feed mechanism of a lathe machine-

1. End of bed gearing
2. Feed gear box
3. Lead screw and feed rod
4. Apron mechanism

The gearing at the end of bed transmits the rotary motion of headstock spindle to the feed gear box. Through the feed gear box the motion is further transmitted either to the feed shaft or lead screw, depending on whether the lathe machine is being used for plain turning or screw cutting.

The feed gear box contains a number of different sizes of gears. The feed gear box provides a means to alter the rate of feed, and the ration between revolutions of the headstock spindle and the movement of carriage for thread cutting by changing the speed of rotation of the feed rod or lead screw.

The apron is fitted to the saddle. It contains gears and clutches to transmit motion from the feed rod to the carriage, and the half nut which engages with the lead screw during cutting threads.

21.3.6 Thread Cutting Mechanism

The half nut or split nut is used for thread cutting in a lathe. It engages or disengages the carriage with the lead screw so that the rotation of the leadscrew is used to traverse the tool along the workpiece to cut screw threads. The direction in which the carriage moves depends upon the position of the feed reverse lever on the headstock.

21.4 ACCESSORIES AND ATTACHMENTS OF LATHE

There are many lathe accessories provided by the lathe manufacturer along with the lathe, which support the lathe operations. The important lathe accessories include centers, catch plates and carriers, chucks, collets, face plates, angle plates, mandrels, and rests. These are used either for holding and supporting the work or for holding the tool. Attachments are additional equipments provided by the lathe manufacturer along with the lathe, which can be used for specific operations. The lathe attachment include stops, ball turning rests, thread chasing dials, milling attachment, grinding attachment, gear cutting attachment, turret attachment and crank pin turning attachments and taper turning attachment.

Lathe centers

The most common method of holding the job in a lathe is between the two centers generally known as live centre (head stock centre) and dead centre (tailstock centre). They are made of very hard materials to resist deflection and wear and they are used to hold and support the cylindrical jobs.

Carriers or driving dog and catch plates

These are used to drive a job when it is held between two centers. Carriers or driving dogs are attached to the end of the job by a setscrew. A use of lathe dog for holding and supporting the job is shown in Fig. 21.6. Catch plates are either screwed or bolted to the nose of the headstock spindle. A projecting pin from the catch plate or carrier fits into the slot provided in either of them. This imparts a positive drive between the lathe spindle and job.

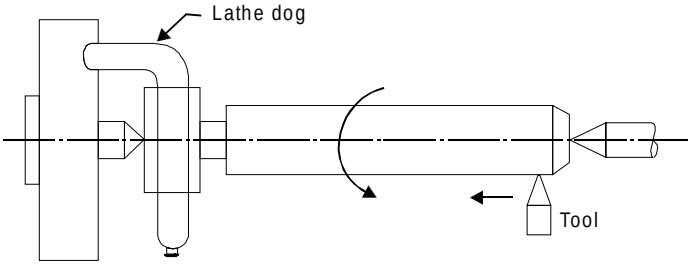


Fig. 21.6 Lathe dog

Chucks

Chuck is one of the most important devices for holding and rotating a job in a lathe. It is basically attached to the headstock spindle of the lathe. The internal threads in the chuck fit on to the external threads on the spindle nose. Short, cylindrical, hol1ow objects or those of irregular shapes, which cannot be conveniently mounted between centers, are easily and rigidly held in a chuck. Jobs of short length and large diameter or of irregular shape, which cannot be conveniently mounted between centers, are held quickly and rigidly in a chuck. There are a number of types of lathe chucks, e.g.

(1) Three jaws or universal
(2) Four jaw independent chuck
(3) Magnetic chuck
(4) Collet chuck
(5) Air or hydraulic chuck operated chuck
(6) Combination chuck
(7) Drill chuck.

Face plates

Face plates are employed for holding jobs, which cannot be conveniently held between centers or by chucks. A face plate possesses the radial, plain and T slots for holding jobs or work-pieces by bolts and clamps. Face plates consist of a circular disc bored out and threaded to fit the nose of the lathe spindle. They are heavily constructed and have strong thick ribs on the back. They have slots cut into them, therefore nuts, bolts, clamps and angles are used to hold the jobs on the face plate. They are accurately machined and ground.

Angle plates

Angle plate is a cast iron plate having two faces machined to make them absolutely at right angles to each other. Holes and slots are provided on both faces so that it may be clamped on a faceplate and can hold the job or workpiece on the other face by bolts and clamps. The plates are used in conjunction with a face plate when the holding surface of the job should be kept horizontal.

Mandrels

A mandrel is a device used for holding and rotating a hollow job that has been previously drilled or bored. The job revolves with the mandrel, which is mounted between two centers.

It is rotated by the lathe dog and the catch plate and it drives the work by friction. Different types of mandrels are employed according to specific requirements. It is hardened and tempered steel shaft or bar with 60° centers, so that it can be mounted between centers. It holds and locates a part from its center hole. The mandrel is always rotated with the help of a lathe dog; it is never placed in a chuck for turning the job. A mandrel unlike an arbor is a job holding device rather than a cutting tool holder. A bush can be faced and turned by holding the same on a mandrel between centers. It is generally used in order to machine the entire length of a hollow job

Rests

A rest is a lathe device, which supports a long slender job, when it is turned between centers or by a chuck, at some intermediate point to prevent bending of the job due to its own weight and vibration set up due to the cutting force that acts on it. The two types of rests commonly used for supporting a long job in an engine lathe are the steady or centre rest and the follower rest.

21.5 SPECIFICATION OF LATHE

The size of a lathe is generally specified by the following means:

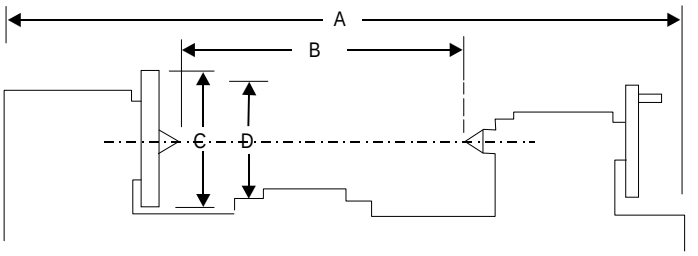
(*a*) Swing or maximum diameter that can be rotated over the bed ways

(*b*) Maximum length of the job that can be held between head stock and tail stock centres

(*c*) Bed length, which may include head stock length also

(*d*) Maximum diameter of the bar that can pass through spindle or collect chuck of capstan lathe.

Fig. 21.7 illustrates the elements involved in specifications of a lathe. The following data also contributes to specify a common lathe machine.



A - Length of bed.
B - Distance between centres.
C - Diameter of the work that can be turned over the ways.
D - Diameter of the work that can be turned over the cross slide.

Fig. 21.7 Specifications of a lathe

(*i*) Maximum swing over bed

(*ii*) Maximum swing over carriage

(*iii*) Height of centers over bed

(*iv*) Maximum distance between centers

(*v*) Length of bed

(*vi*) Width of bed
(*vii*) Morse taper of center
(*viii*) Diameter of hole through spindle
(*ix*) Face plate diameter
(*x*) Size of tool post
(*xi*) Number of spindle speeds
(*xii*) Lead screw diameter and number of threads per cm.
(*xiii*) Size of electrical motor
(*xiv*) Pitch range of metric and inch threads etc.

21.6 LATHE OPERATIONS

For performing the various machining operations in a lathe, the job is being supported and driven by anyone of the following methods.

1. Job is held and driven by chuck with the other end supported on the tail stock centre.
2. Job is held between centers and driven by carriers and catch plates.
3. Job is held on a mandrel, which is supported between centers and driven by carriers and catch plates.
4. Job is held and driven by a chuck or a faceplate or an angle plate.

The above methods for holding the job can be classified under two headings namely job held between centers and job held by a chuck or any other fixture. The various important lathe operations are depicted through Fig. 21.8 (*a*), (*b*) and (*c*). The operations performed in a lathe can be understood by three major categories

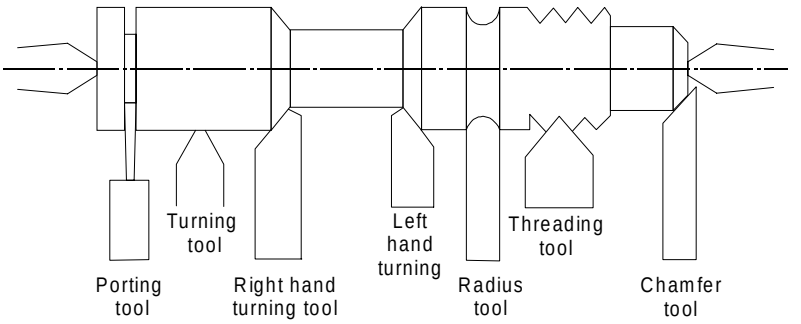


Fig. 21.8(a) Lathe operation

(*a*) Operations, which can be performed in a lathe either by holding the workpiece between centers or by a chuck are:

1. Straight turning
2. Shoulder turning
3. Taper turning
4. Chamfering
5. Eccentric turning
6. Thread cutting
7. Facing
8. Forming
9. Filing
10. Polishing
11. Grooving
12. Knurling
13. Spinning
14. Spring winding

(*b*) Operations which are performed by holding the work by a chuck or a faceplate or an angle plate are:

1. Undercutting
2. Parting-off
3. Internal thread cutting
4. Drilling
5. Reaming
6. Boring
7. Counter boring
8. Taper boring
9. Tapping

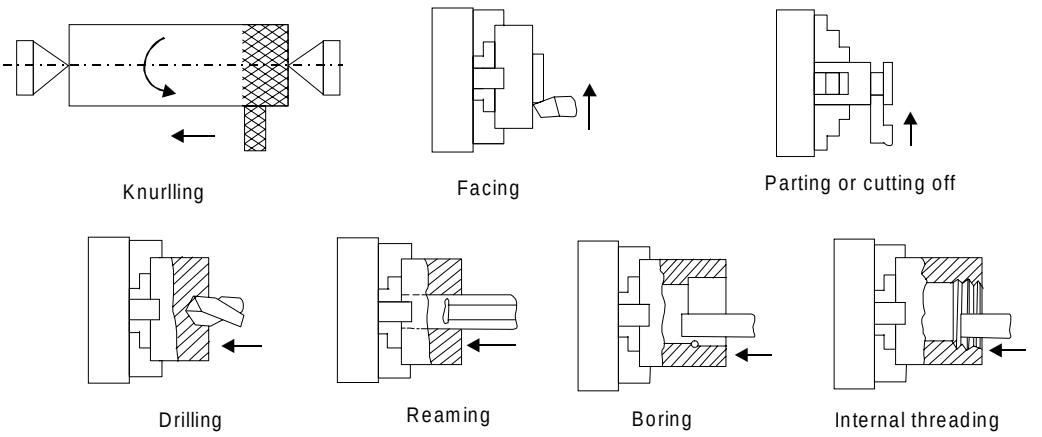


Fig. 21.8(b) Lathe operations

(*c*) Operations which are performed by using special lathe attachments are:

1. Milling
2. Grinding

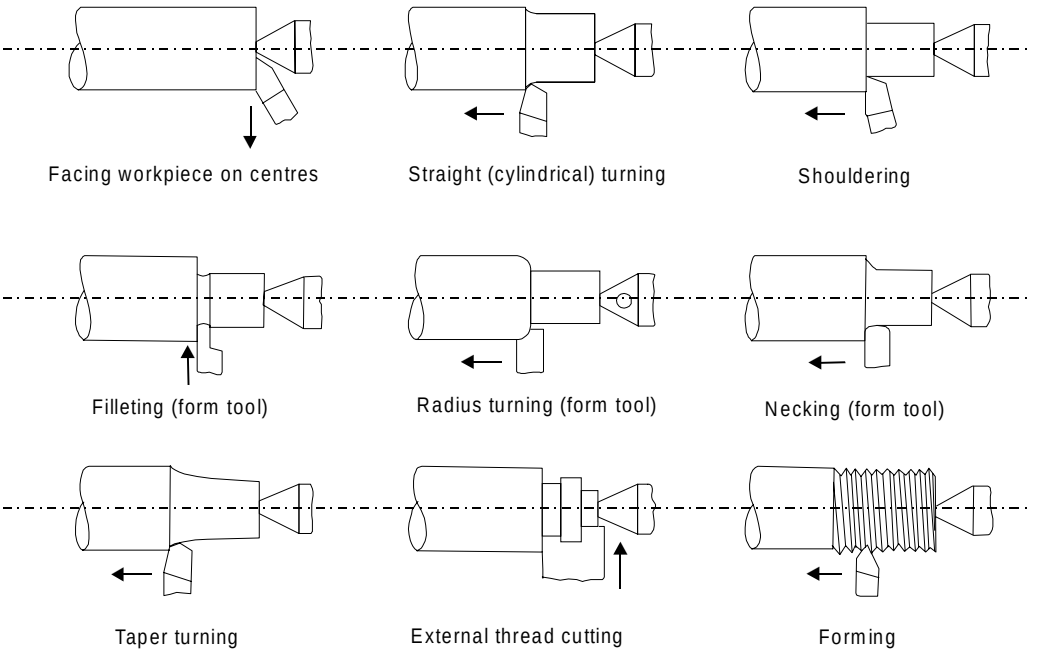


Fig. 21.8(c) Lathe operation

Some of the important operations performed on a lathe machine are discussed as under.

21.7 TAPERS AND TAPER TURNING

A taper is defined as a uniform increase or decrease in diameter of a piece of work measured along its length. In a lathe machine, taper turning means to produce a conical surface by gradual reduction in diameter from a cylindrical job. Taper in the British System is expressed in taper per foot or taper per inch.

$$\text{Taper per inch} = (D - d)/l$$

Where,

D = is the diameter of the large end of cylindrical job,

d = is the diameter of the small end of cylindrical job, and

l = is the length of the taper of cylindrical job, all expressed in inches,

When the taper is expressed in taper per foot, the length of the taper l is expressed in foot, but the diameters are expressed in inches.

A taper is generally turned in a lathe by feeding the tool at an angle to the axis of rotation of the workpiece. The angle formed by the path of the tool with the axis of the workpiece should correspond to the half taper angle. A taper can be turned by anyone of the following methods:

1. By swiveling the compound rest,
2. By setting over the tailstock centre,
3. By a broad nose form tool,
4. By a taper turning attachment,
5. By combining longitudinal and cross feed in a special lathe and
6. By using numerical control lathe

Some of the important taper turning methods are discussed as under.

21.7.1 Taper Turning by Swivelling the Compound Rest

This method uses the principle of turning taper by rotating the workpiece on the lathe axis and feeding the tool at an angle to the axis of rotation of the workpiece. The tool is mounted on the compound rest which is attached to a circular base, graduated in degrees. The compound rest can easily be swiveled or rotated and clamped at any desired angle as shown in Fig. 21.9 (a). Once the compound rest is set at the desired half taper angle, rotation of the compound slide screw will cause the tool to be fed at that angle and generate a corresponding taper. This method is limited to turn a short but steep taper because of the limited movement of the cross-slide. The compound rest can be swiveled at 45° on either side of the lathe axis enabling it to turn a steep taper. The movement of the single point cutting tool in this method is being purely controlled by hand. Thus it provides a low production capacity and poor surface finish. The positioning or setting of the compound rest is accomplished by swiveling the rest at the half taper angle, if this is already known. If the diameter of the small and large end and length of taper are known, the half taper angle can be calculated. The complete setup for producing a taper by swelling the compound rest is given in Fig. 21.9(b)

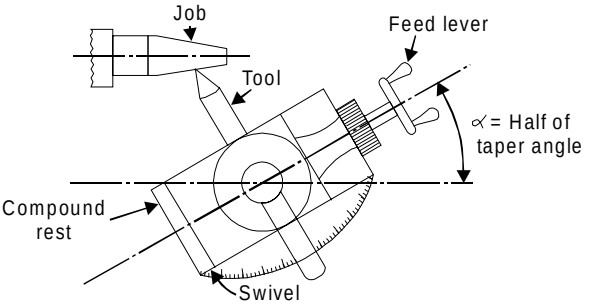


Fig. 21.9(a) Taper turning by swiveling compound rest

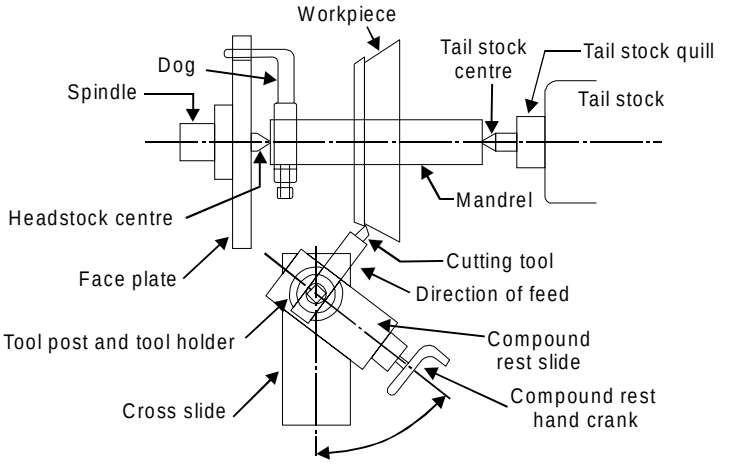


Fig. 21.9(b) Swiveling compound rest set-up

21.7.2 Taper Turning Attachment Method

This method is commonly employed for generating external tapers only. In this method, the taper turning attachment is bolted back of the lathe machine as shown in Fig.21.10. It

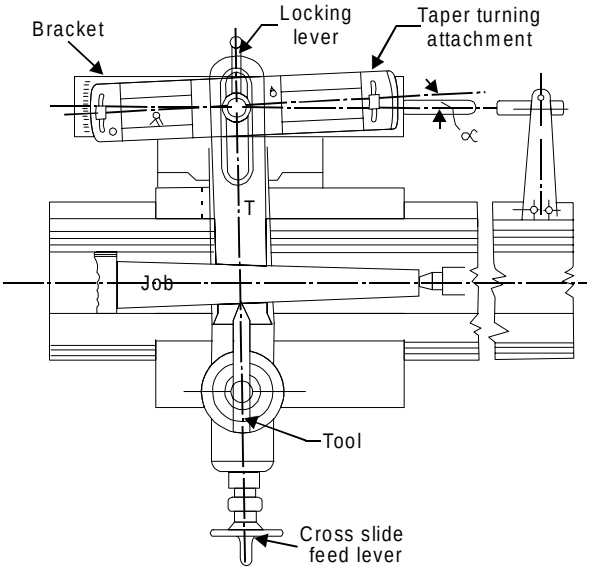


Fig. 21.10 Taper turning attachment

has guide bar which may be set at any desired angle or taper. As the carriage moves along the bed length aside over bar causes the tool to move in and out according to setting of the bar. The taper setting on the bar is duplicated on the job or work. The merit of this method is that the lathe centres are kept in alignment.

21.7.3 Taper Turning with Tailstock set over Method

This method is basically employed for turning small tapers on longer jobs and is confined to external tapers only. In this method, the tailstock is set over is calculated using Fig. 21.11 by loosening the nut from its centre line equal to the value obtained by formula given below.

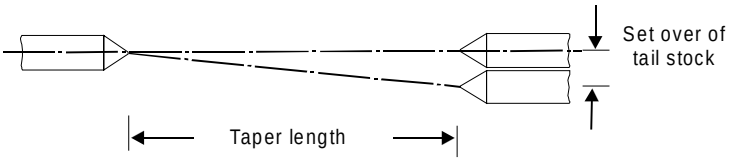


Fig. 21.11 Tailstock set over

$$\text{Tail stock set over} = \text{Taper length} \times \text{Sine of half of taper angle}$$

$$(D - d) / 2 = l \times \sin (a/2)$$

Where, D = is the diameter of the large end of cylindrical job,

d = is the diameter of the small end of cylindrical job, and

l = is the length of the taper of cylindrical job, all expressed in inches,

a = taper angle

When a part length of the job is to be given taper then tail stock set

$= ((D - d)/2)) \times$ (total length of the cylindrical job/length of taper)

$= l \times \sin (a/2) \times$ (total length of the cylindrical job/length of taper)

21.7.4 Form Tool Method

Fig. 21.12 shows this method in which a taper form is used to obtain tapers. It is limited to short external tapers. The edge tool must be exactly straight for accurate work.

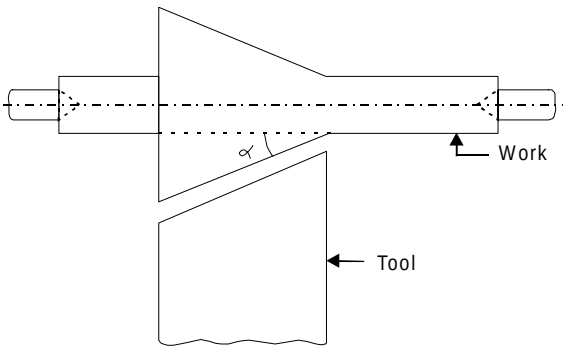


Fig. 21.12 Form tool taper turning

21.7.5 Taper Turning with Double Feeds

Taper turning can also be cut by combining the two feeds. Fig. 21.13 shows this arrangement of taper turning, which is good method of taper turning. In certain lathes both

longitudinal and cross feeds may be engaged simultaneously causing the tool to follow a diagonal point which is the resultant of the magnitude of the two feeds. The direction of resultant feed may be changed by varying the rate of feeds by change gears provided inside the apron of the lathe.

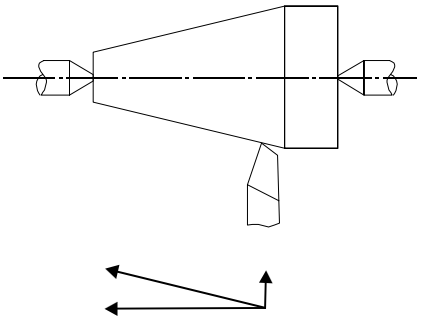


Fig. 21.13 Taper turning using combined feeds

21.8 THREAD CUTTING

Fig.21.14 shows the setup of thread cutting on a lathe. Thread of any pitch, shape and size can be cut on a lathe using single point cutting tool. Thread cutting is operation of producing a helical groove on spindle shape such as V, square or power threads on a cylindrical surface. The job is held in between centres or in a chuck and the cutting tool is held on tool post. The cutting tool must travel a distance equal to the pitch (in mm) as the work piece completes a revolution. The definite relative rotary and linear motion between job and cutting tool is achieved by locking or engaging a carriage motion with lead screw and nut mechanism and fixing a gear ratio between head stock spindle and lead screw. To make or cut threads, the cutting tool is brought to the start of job and a small depth of cut is given to cutting tool using cross slide.

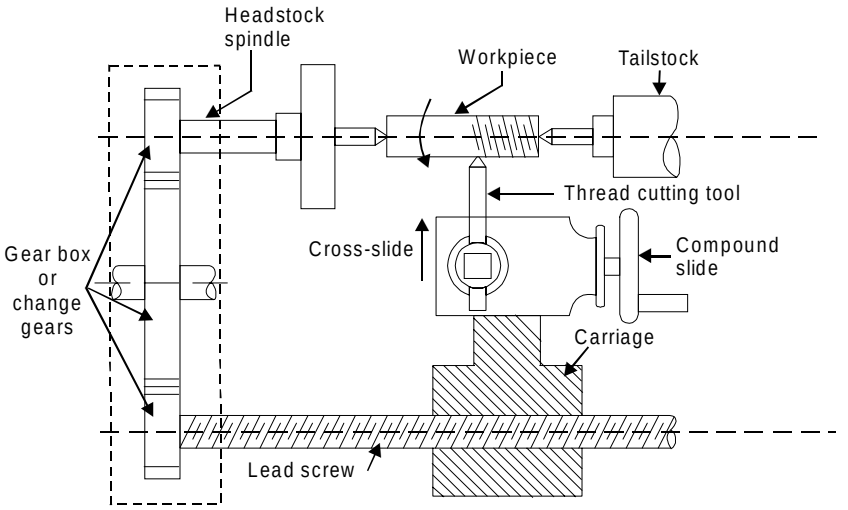


Fig. 21.14 Thread cutting

21.9 DRILLING ON A LATHE

For producing holes in jobs on lathe, the job is held in a chuck or on a face plate. The drill is held in the position of tailstock and which is brought nearer the job by moving the tailstock along the guide ways, the thus drill is fed against the rotating job as shown in Fig. 21.15.

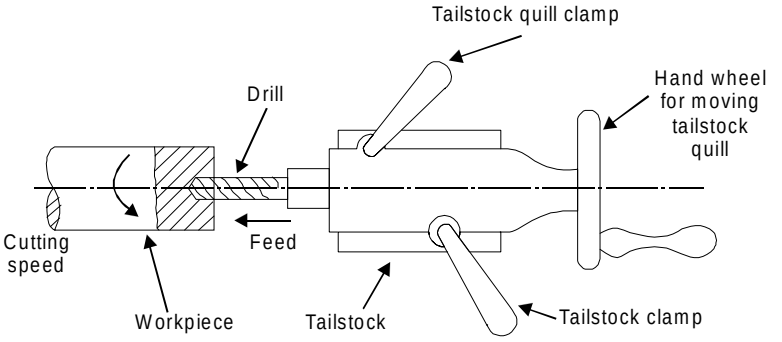


Fig. 21.15 Drilling on lathe

21.10 CUTTING SPEED

Cutting speed for lathe work may be defined as the rate in meters per minute at which the surface of the job moves past the cutting tool. Machining at a correct cutting speed is highly important for good tool life and efficient cutting. Too slow cutting speeds reduce productivity and increase manufacturing costs whereas too high cutting speeds result in overheating of the tool and premature failure of the cutting edge of the tool. The following factors affect the cutting speed:

(*i*) Kind of material being cut,

(*ii*) Cutting tool material,

(*iii*) Shape of cutting tool,

(*iv*) Rigidity of machine tool and the job piece and

(*v*) Type of cutting fluid being used.

Calculation of cutting speed Cs, in meters per minute

$$Cs = ((22/7) \times D \times N)) /1000$$

Where

D is diameter of job in mm.

N is in RPM

21.11 FEED

Feed is defined as the distance that a tool advances into the work during one revolution of the headstock spindle. It is usually given as a linear movement per revolution of the spindle or job. During turning a job on the center lathe, the saddle and the tool post move along the bed of the lathe for a particular feed for cutting along the length of the rotating job.

22.12 QUESTIONS

1. Describe the working principle of the lathe.
2. Name the different types of the lathes available in machine shop? Describe the working of a centre lathe.
3. Explain the parts of a centre lathe using neat sketch.
4. Explain following parts of a lathe by neat sketches:
   (*i*) Lathe Bed (*ii*) Carriage (*iii*) Headstock (*iv*) Tailstock
5. How can you specify a lathe?
6. Name the operations, which can be performed on a lathe.
7. Lists the accessories of a lathe? Explain them with neat sketches.
8. Describe any two work holding devices used on the lathe.
9. What is the use of follower rest and steady rest?
10. Explain the difference between three jaw chuck and four jaw chuck.
11. Using neat sketches, describe the various operations that can be carried on lathe machines.
12. With the help of a line diagram, describe the gear mechanism of an engine lathe.
13. Discuss the merits and demerits of a geared-head drive over cone-pulley drive.
14. Name and sketch the different types of the cutting tools of the lathe.
15. Describe the procedure of cutting right hand V- heads of the lathe.
16. With help of neat diagram, describe the following:
   (*i*) Finish turning
   (*ii*) Rough turning
   (*iii*) Turning
   (*iv*) Drilling
   (*v*) Attachments of lathe
17. Name different methods of taper turning? Describe these methods using neat sketches.
18. Describe with suitable sketch the procedure for turning a taper using setting over the tailstock.
19. Define the following terms used in lathe operation.
   (*i*) Cutting speed
   (*ii*) Feed
   (*iii*) Depth of cut
   (*iv*) Machining time

22
CHAPTER

DRILLING MACHINE

22.1 INTRODUCTION

Drilling is an operation of making a circular hole by removing a volume of metal from the job by cutting tool called drill. A drill is a rotary end-cutting tool with one or more cutting lips and usually one or more flutes for the passage of chips and the admission of cutting fluid. A drilling machine is a machine tool designed for drilling holes in metals. It is one of the most important and versatile machine tools in a workshop. Besides drilling round holes, many other operations can also be performed on the drilling machine such as counter- boring, countersinking, honing, reaming, lapping, sanding etc.

22.2 CONSTRUCTION OF DRILLING MACHINE

In drilling machine the drill is rotated and fed along its axis of rotation in the stationary workpiece. Different parts of a drilling machine are shown in Fig. 22.1 and are discussed below: (*i*) The head containing electric motor, V-pulleys and V-belt which transmit rotary motion to the drill spindle at a number of speeds. (*ii*) Spindle is made up of alloy steel. It rotates as well as moves up and down in a sleeve. A pinion engages a rack fixed onto the sleeve to provide vertical up and down motion of the spindle and hence the drill so that the same can be fed into the workpiece or withdrawn from it while drilling. Spindle speed or the drill speed is changed with the help of V-belt and V-step-pulleys. Larger drilling machines are having gear boxes for the said purpose. (*iii*) Drill chuck is held at the end of the drill spindle and in turn it holds the drill bit. (*iv*) Adjustable work piece table is supported on the column of the drilling machine. It can be moved both vertically and horizontally. Tables are generally having slots so that the vise or the workpiece can be securely held on it. (*v*) Base table is a heavy casting and it supports the drill press structure. The base supports the column, which in turn, supports the table, head etc. (*vi*) Column is a vertical round or box section which rests on the base and supports the head and the table. The round column may have rack teeth cut on it so that the table can be raised or lowered depending upon the workpiece requirements. This machine consists of following parts

1. Base
2. Pillar
3. Main drive
4. Drill spindle

5. Feed handle
6. Work table

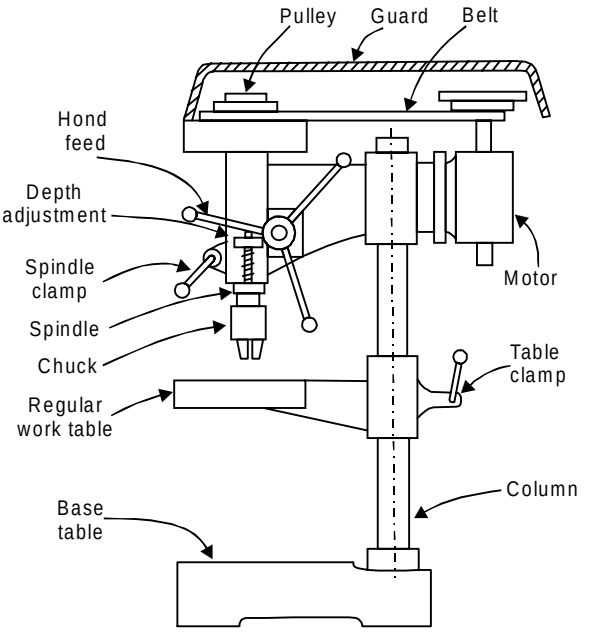


Fig. 22.1 Construction of drilling machine

22.3 TYPES OF DRILLING MACHINE

Drilling machines are classified on the basis of their constructional features, or the type of work they can handle. The various types of drilling machines are:

(1) Portable drilling machine
(2) Sensitive drilling machine
  (*a*) Bench mounting
  (*b*) Floor mounting
(3) Upright drilling machine
  (*a*) Round column section
  (*b*) Box column section machine
(4) Radial drilling machine
  (*a*) Plain
  (*b*) Semi universal
  (*c*) Universal
(5) Gang drilling machine
(6) Multiple spindle drilling machine
(7) Automatic drilling machine
(8) Deep hole drilling machine

(*a*) Vertical

(*b*) Horizontal

Few commonly used drilling machines are described as under.

22.3.1 Portable Drilling Machine

A portable drilling machine is a small compact unit and used for drilling holes in worpieces in any position, which cannot be drilled in a standard drilling machine. It may be used for drilling small diameter holes in large castings or weldments at that place itself where they are lying. Portable drilling machines are fitted with small electric motors, which may be driven by both A.C. and D.C. power supply. These drilling machines operate at fairly high speeds and accommodate drills up to 12 mm in diameter.

22.3.2 Sensitive Drilling Machine

It is a small machine used for drilling small holes in light jobs. In this drilling machine, the workpiece is mounted on the table and drill is fed into the work by purely hand control. High rotating speed of the drill and hand feed are the major features of sensitive drilling machine. As the operator senses the drilling action in the workpiece, at any instant, it is called sensitive drilling machine. A sensitive drilling machine consists of a horizontal table, a vertical column, a head supporting the motor and driving mechanism, and a vertical spindle. Drills of diameter from 1.5 to 15.5 mm can be rotated in the spindle of sensitive drilling machine. Depending on the mounting of base of the machine, it may be classified into following types:

1. Bench mounted drilling machine, and
2. Floor mounted drilling machine

22.3.3 Upright Drilling Machine

The upright drilling machine is larger and heavier than a sensitive drilling machine. It is designed for handling medium sized workpieces and is supplied with power feed arrangement. In this machine a large number of spindle speeds and feeds may be available for drilling different types of work. Upright drilling machines are available in various sizes and with various drilling capacities (ranging up to 75 mm diameter drills). The table of the machine also has different types of adjustments. Based on the construction, there are two general types of upright drilling machine:

(1) Round column section or pillar drilling machine.

(2) Box column section.

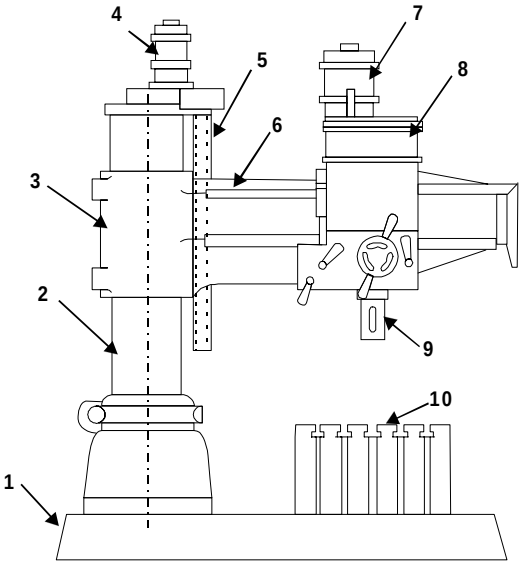
The round column section upright drilling machine consists of a round column whereas the upright drilling machine has box column section. The other constructional features of both are same. Box column machines possess more machine strength and rigidity as compared to those having round section column.

22.3.4 Radial Drilling Machine

Fig. 22.2 illustrates a radial drilling machine. The radial drilling machine consists of a heavy, round vertical column supporting a horizontal arm that carries the drill head. Arm can be raised or lowered on the column and can also be swung around to any position over the work and can be locked in any position. The drill head containing mechanism for rotating and

feeding the drill is mounted on a radial arm and can be moved horizontally on the guide-ways and clamped at any desired position. These adjustments of arm and drilling head permit the operator to locate the drill quickly over any point on the work. The table of radial drilling machine may also be rotated through 360 deg. The maximum size of hole that the machine can drill is not more than 50 mm. Powerful drive motors are geared directly into the head of the machine and a wide range of power feeds are available as well as sensitive and geared manual feeds. The radial drilling machine is used primarily for drilling medium to large and heavy workpieces. Depending on the different movements of horizontal arm, table and drill head, the upright drilling machine may be classified into following types-

1. Plain radial drilling machine
2. Semi universal drilling machine, and
3. Universal drilling machine.



Parts name

1.	Base	6.	Guide ways
2.	Column	7.	Motor for driving drill spindle
3.	Radial arm	8.	Drill head
4.	Motor for elevating arm	9.	Drill spindle
5.	Elevating screw	10.	Table

Fig. 22.2 Radial drilling machine

In a plain radial drilling machine, provisions are made for following three movements -

1. Vertical movement of the arm on the column,
2. Horizontal movement of the drill head along the arm, and
3. Circular movement of the arm in horizontal plane about the vertical column.

In a semi universal drilling machine, in addition to the above three movements, the drill head can be swung about a horizontal axis perpendicular to the arm. In universal machine, an additional rotatory movement of the arm holding the drill head on a horizontal axis is also provided for enabling it to drill on a job at any angle.

22.3.5 Gang Drilling Machine

In gang drilling machine, a number of single spindle drilling machine columns are placed side by side on a common base and have a common worktable. A series of operation may be performed on the job by shifting the work from one position to the other on the worktable. This type of machine is mainly used for production work.

22.3.6 Multiple-Spindle Drilling Machine

The multiple-spindle drilling machine is used to drill a number of holes in a job simultaneously and to reproduce the same pattern of holes in a number of identical pieces in a mass production work. This machine has several spindles and all the spindles holding drills are fed into the work simultaneously. Feeding motion is usually obtained by raising the worktable.

22.4 TYPES OF DRILLS

A drill is a multi point cutting tool used to produce or enlarge a hole in the workpiece. It usually consists of two cutting edges set an angle with the axis. Broadly there are three types of drills:

1. Flat drill,
2. Straight-fluted drill, and
3. Twist drill

Flat drill is usually made from a piece of round steel which is forged to shape and ground to size, then hardened and tempered. The cutting angle is usually 90 deg. and the relief or clearance at the cutting edge is 3 to 8 deg. The disadvantage of this type of drill is that each time the drill is ground the diameter is reduced. Twist drill is the most common type of drill in use today. The various types of twist drills (parallel shank type and Morse taper shank type) are shown in Fig. 22.3

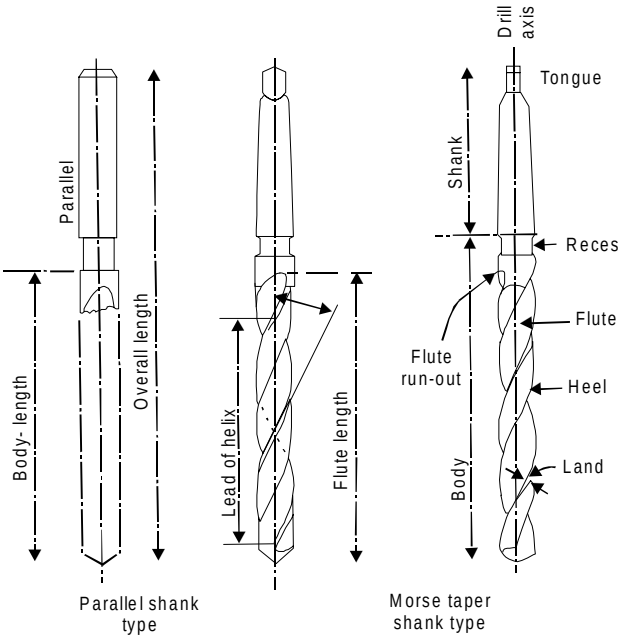


Fig. 22.3 Types of twist drill

Number sizes

In metric system, the drill is generally manufactured from 0.2 to 100 mm. In British system the drills sizes range from No. 1 to No. 80. Number 80 is the smallest having diameter equal to 0.0135 inch and the number 1 is the largest having diameter equal to 0.228 inch. Number 1 to number 60 is the standard sets of drills. The numbers 61 to 80 sizes drills are not so commonly used. The diameter of drills increases in steps of approximately by 0.002 inch.

Letter sizes

The drill sizes range from A to Z, A being the smallest having diameter equal to 0.234 inch and Z being the largest having diameter equal to 0.413 inch, increasing in steps of approximately O.010 inch fractional sizes: The drill sizes range from 1/64″ inch to 5 inch in steps of 1/64 inches up to 1.75 inches, then the steps gradually increase. The drill sizes range from A to Z, A being the smallest having diameter equal to 0.234 inch and Z being the largest having diameter equal to 0.413 inch, increasing in steps of approximately O.010 inch fractional sizes: The drill sizes range from 1/64″ inch to 5 inch in steps of 1/64 inches up to 1.75 inches, then the steps gradually increase.

The drill is generally removed by tapping a wedge shaped drift into the slot in the drilling machine spindle as shown in Fig. 22.4.

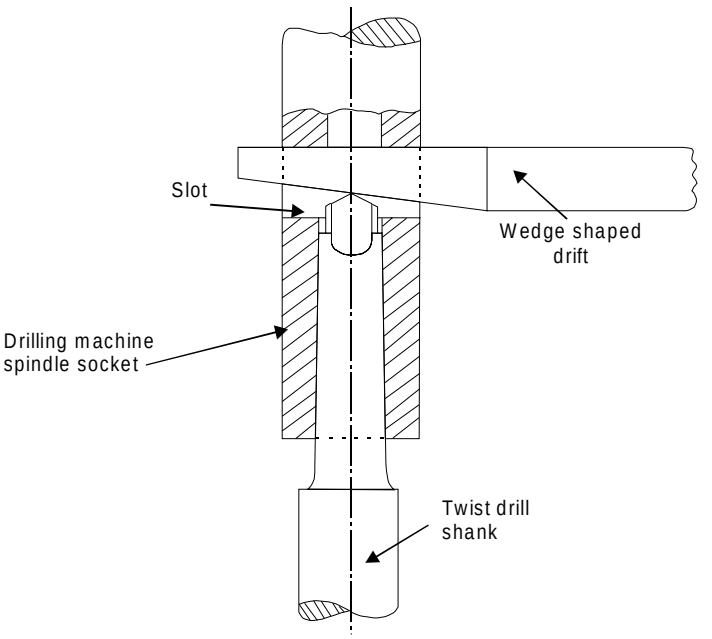


Fig. 22.4 Removing a drill from drill machine

22.4.1 Twist Drill Geometry

Twist drill geometry and its nomenclature are shown in Fig. 22.5. A twist drill has three principal parts:

(*i*) Drill point or dead center

(*ii*) Body

(*iii*) Shank.

Drill axis is the longitudinal centre line.

Drill point is the sharpened end of the drill body consisting of all that part which is shaped to produce lips, faces and chisel edge.

Lip or cutting edge is the edge formed by the intersection of the flank and face

Lip length is the minimum distance between the outer corner and the chisel-edge corner of the lip.

Face is that portion of the flute surface adjacent to the lip on which the chip impinges as it is cut from the work.

Chisel edge is the edge formed by the intersection of the flanks.

Flank is that surface on a drill point which extends behind the lip to the following flute.

Flutes are the grooves in the body of the drill, which provide lips, allow the removal of chips, and permit cutting fluid to reach the lips.

Flute length is the axial length from the extreme end of the point to the termination of the flutes at the shank end of the body.

Body is that portion of the drill nomenclature, which extends from the extreme cutting end to the beginning of the shank.

Shank is that portion of the drill by which it is held and driven,

Heel is the edge formed by the intersection of the flute surface and the body clearance.

Body clearance is that portion of the body surface reduced in diameter to provide diametric clearance.

Core or web is the central portion of the drill situated between the roots of the flutes and extending from the point end towards the shank; the point end of the core forms the chisel edge.

Lands are the cylindrically ground surfaces on the leading edges of the drill flutes. The width of the land is measured at right angles to the flute.

Recess is the portion of the drill body between the flutes and the shank provided so as to facilitate the grinding of the body. Parallel shank drills of small diameter are not usually provided with a recess.

Outer corner is the corner formed by the intersection of the lip and the leading edge of the land.

Chisel edge comer is the corner formed by the intersection of a lip and the chisel edge.

Drill diameter is the measurement across the cylindrical lands at the outer corners of the drill. .

Lead of helix is the distance measured parallel to the drill axis between corresponding points on the leading edge of a flute in one complete turn of the flute.

Helix angle is the angle between the leading edge of the land and the drill axis.

Rake angle is the angle between the face and a line parallel to the drill axis. It is bigger at the face edges and decreases towards the center of the drill to nearly 0°. The result is that the formation of chips grows more un-favorable towards the centre.

Lip clearance angle is the angle formed by the flank and a plane at right angles to the drill axis; the angle is normally measured at the periphery of the drill. To make sure that

the main cutting edges can enter into the material, the clearance faces slope backwards in a curve. The clearance angle is measured at the face edge, must amount to 5° up to 8°.

Point angle is the included angle of the cone formed by the lips.

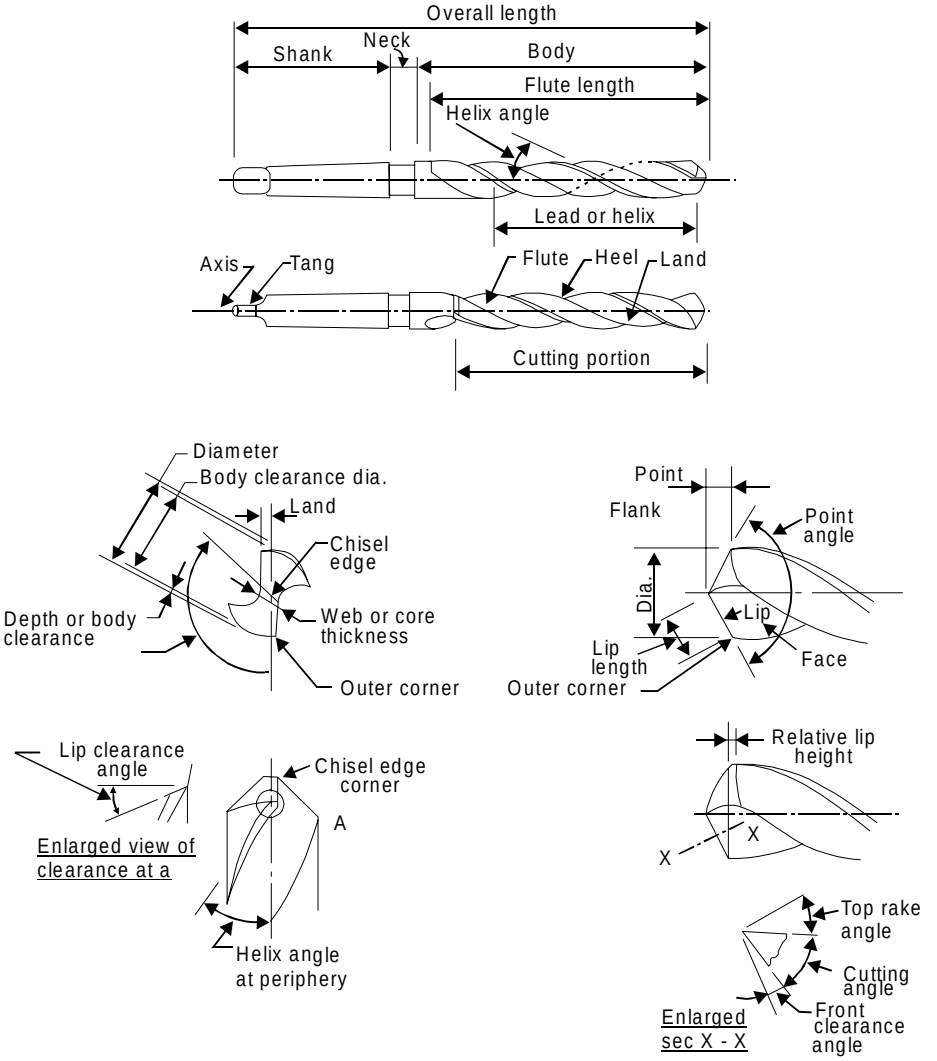


Fig. 22.5 Geometry and nomenclature of twist drill

22.4.2 Drill Material

Drills are made are made up of high speed steel. High speed steel is used for about 90 per cent of all twist drills. For metals more difficult to cut, HSS alloys of high cobalt series are used.

22.5 OPERATIONS PERFORMED ON DRILLING MACHINE

A drill machine is versatile machine tool. A number of operations can be performed on it. Some of the operations that can be performed on drilling machines are:

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Countersinking
6. Spot facing
7. Tapping
8. Lapping
9. Grinding
10. Trepanning.

The operations that are commonly performed on drilling machines are drilling, reaming, lapping, boring, counter-boring, counter-sinking, spot facing, and tapping. These operations are discussed as under.

22.5.1 Drilling

This is the operation of making a circular hole by removing a volume of metal from the job by a rotating cutting tool called drill as shown in Fig. 22.6. Drilling removes solid metal from the job to produce a circular hole. Before drilling, the hole is located by drawing two lines at right angle and a center punch is used to make an indentation for the drill point at the center to help the drill in getting started. A suitable drill is held in the drill machine and the drill machine is adjusted to operate at the correct cutting speed. The drill machine is started and the drill starts rotating. Cutting fluid is made to flow liberally and the cut is started. The rotating drill is made to feed into the job. The hole, depending upon its length, may be drilled in one or more steps. After the drilling operation is complete, the drill is removed from the hole and the power is turned off.

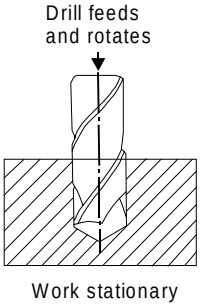


Fig. 22.6 Drilling operation

22.5.2 Reaming

This is the operation of sizing and finishing a hole already made by a drill. Reaming is performed by means of a cutting tool called reamer as shown in Fig. 22.7. Reaming operation serves to make the hole smooth, straight and accurate in diameter. Reaming operation is performed by means of a multitooth tool called reamer. Reamer possesses several cutting edges on outer periphery and may be classified as solid reamer and adjustable reamer.

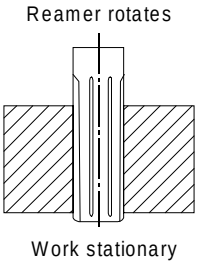


Fig. 22.7 Reaming operation

22.5.3 Boring

Fig. 22.8 shows the boring operation where enlarging a hole by means of adjustable cutting tools with only one cutting edge is accomplished. A boring tool is employed for this purpose.

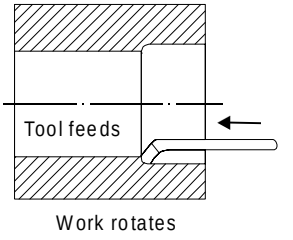


Fig. 22.8 Boring operation

22.5.4 Counter-Boring

Counter boring operation is shown in Fig. 22.9. It is the operation of enlarging the end of a hole cylindrically, as for the recess for a counter-sunk rivet. The tool used is known as counter-bore.

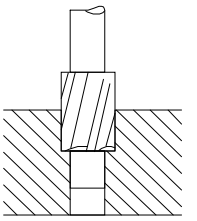


Fig. 22.9 Counter boring operation

22.5.5 Counter-Sinking

Counter-sinking operation is shown in Fig. 22.10. This is the operation of making a cone-shaped enlargement of the end of a hole, as for the recess for a flat head screw. This is done for providing a seat for counter sunk heads of the screws so that the latter may flush with the main surface of the work.

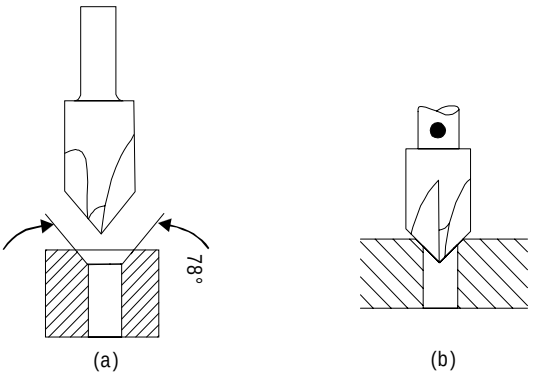


Fig. 22.10 Counter sinking operation

22.5.6 Lapping

This is the operation of sizing and finishing a hole by removing very small amounts of material by means of an abrasive. The abrasive material is kept in contact with the sides of a hole that is to be lapped, by the use of a lapping tool.

22.5.7 Spot-Facing

This is the operation of removing enough material to provide a flat surface around a hole to accommodate the head of a bolt or a nut. A spot-facing tool is very nearly similar to the counter-bore

22.5.8 Tapping

It is the operation of cutting internal threads by using a tool called a tap. A tap is similar to a bolt with accurate threads cut on it. To perform the tapping operation, a tap is screwed into the hole by hand or by machine. The tap removes metal and cuts internal threads, which will fit into external threads of the same size. For all materials except cast iron, a little lubricate oil is applied to improve the action. The tap is not turned continuously, but after every half turn, it should be

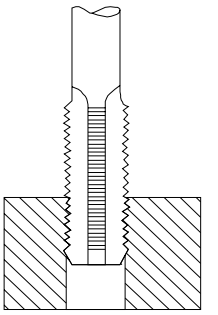


Fig. 22.11 Tapping operation

reversed slightly to clear the threads. Tapping operation is shown in Fig.22.11. The geometry and nomenclature of a tap is given in Fig. 22.12.

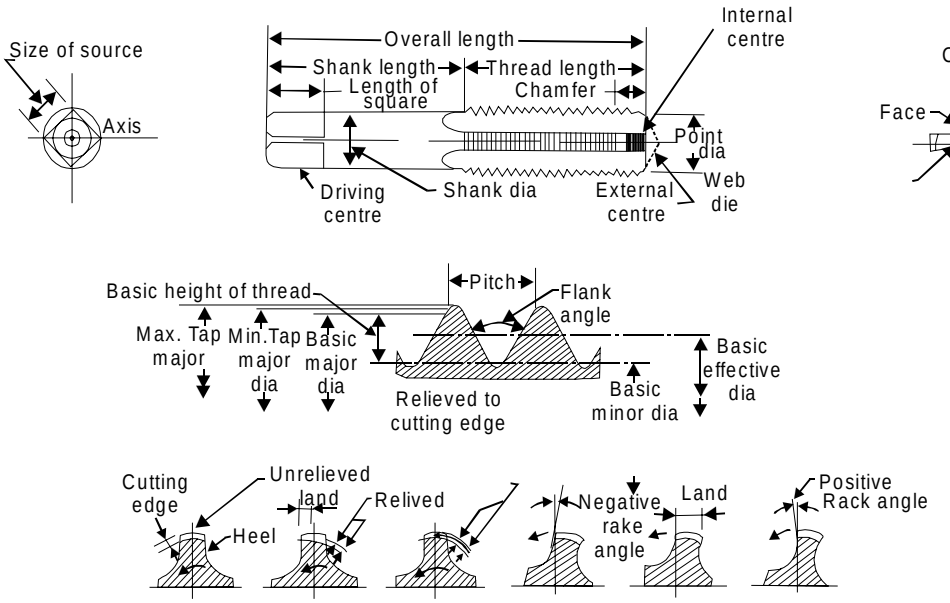


Fig. 22.12 Geometry and nomenclature of tap

22.5.9 Core drilling

Core drilling operation is shown in Fig. 22.13. It is a main operation, which is performed on radial drilling machine for producing a circular hole, which is deep in the solid metal by means of revolving tool called drill.

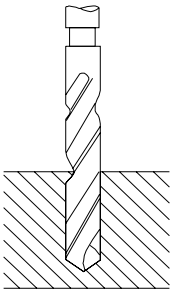


Fig. 22.13 Core drilling operation

22.6 SIZE OF A DRILLING MACHINE

Different parameters are being considered for different types of drilling machines to determine their size. The size of a portable drilling machine is decided by the maximum diameter of the drill that it can hold. The sensitive and upright drilling machines are specified by the diameter of the largest workpiece which can be centered under the drill machine spindle. A radial drilling machine is specified by the length of the arm and the diameter of the column. To specify a drilling machine completely, following other parameters may also be needed:

1. Table diameter
2. Number of spindle speeds and feeds available
3. Maximum spindle travel
4. Morse taper number of the drill spindle
5. Power input
6. Net weight of the machine
7. Floor space required, etc.

22.7 CUTTING SPEED

The cutting speed in a drilling operation refers to the peripheral speed of a point on the surface of the drill in contact with the work. It is usually expressed in meters/min. The cutting speed (C_s) may be calculated as:

$$C_s = ((22/7) \times D \times N)/1000$$

Where, D is the diameter of the drill in mm and

N is the rpm of the drill spindle.

22.8 FEED

The feed of a drill is the distance the drill moves into the job at each revolution of the spindle. It is expressed in millimeter. The feed may also be expressed as feed per minute. The feed per minute may be defined as the axial distance moved by the drill into the work per minute. The feed per minute may be calculated as:

$$F = F_r \times N$$

Where, F = Feed per minute in mm.

F_r = Feed per revolution in mm.

N = R.P.M. of the drill.

22.9 QUESTIONS

1. State the working principle of a drilling machine.
2. Explain principal parts of the drilling machine and sketch the mechanism of a drilling machine.
3. Give the classification of drilling machines.
4. How will you specify a drilling machine?
5. What operations can be done on a drilling machine? Discuss them with diagrams.
6. With the help of a line diagram, describe the construction of radial drilling machine.
7. List the devices commonly used for holding the work on a drilling machine, and describe any three.
8. Define cutting speed, feed and machining time for drilling.
9. Sketch a twist drill and name its different parts.
10. What is boring? Sketch a boring tool.
11. What is the function of flutes on a twist drill bit? Why are straight flute drills used for non-ferrous materials and metal?
12. Draw suitable figure for a drill bit showing:
    (*i*) point (*ii*) lip clearance (*iii*) point angle (*iv*) flute (*v*) margin and (*vi*) body clearance
13. Write short notes on following:
    (*i*) Drilling (*ii*) Boring, (*iii*) Reaming (*iv*) Tapping (*v*) Counter boring (*vi*) Counter sinking
14. Explain various types of operations performed on a drilling machine by neat sketches.
15. Define the following terms used in drilling operation.
    (*i*) Cutting speed (*ii*) Feed

23
CHAPTER

SHAPER, PLANER AND SLOTTER

23.1 SHAPER

Shaper is a reciprocating type of machine tool in which the ram moves the cutting tool backwards and forwards in a straight line. The basic components of shaper are shown in Fig. 23.1. It is intended primarily to produce flat surfaces. These surfaces may be horizontal, vertical, or inclined. In general, the shaper can produce any surface composed of straight-line elements. The principal of shaping operation is shown in Fig. 23.2 (a, b). Modern shapers can also generate contoured surface as shown in Fig. 23.3. A shaper is used to generate flat (plane) surfaces by means of a single point cutting tool similar to a lathe tool.

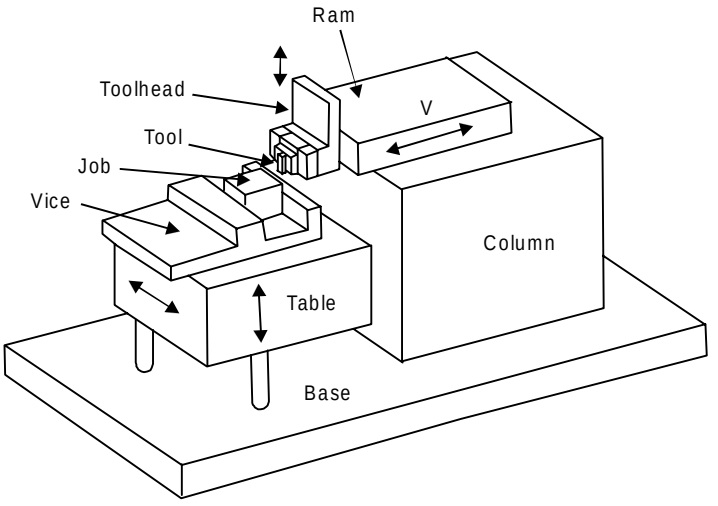


Fig. 23.1 Principal components of a shaper

23.2 WORKING PRINCIPLE OF SHAPER

A single point cutting tool is held in the tool holder, which is mounted on the ram. The workpiece is rigidly held in a vice or clamped directly on the table. The table may be supported at the outer end. The ram reciprocates and thus cutting tool held in tool holder moves forward and backward over the workpiece. In a standard shaper, cutting of material

takes place during the forward stroke of the ram. The backward stroke remains idle and no cutting takes place during this stroke. The feed is given to the workpiece and depth of cut is adjusted by moving the tool downward towards the workpiece. The time taken during the idle stroke is less as compared to forward cutting stroke and this is obtained by quick return mechanism. The cutting action and functioning of clapper box is shown in Fig.23.4 during forward and return stroke.

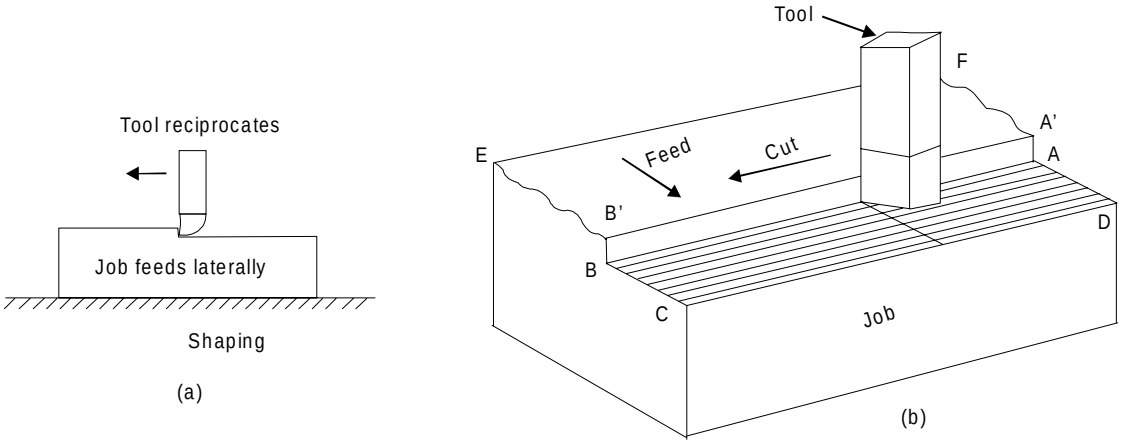


Fig. 23.2 (a, b) Working principal of shaping machine

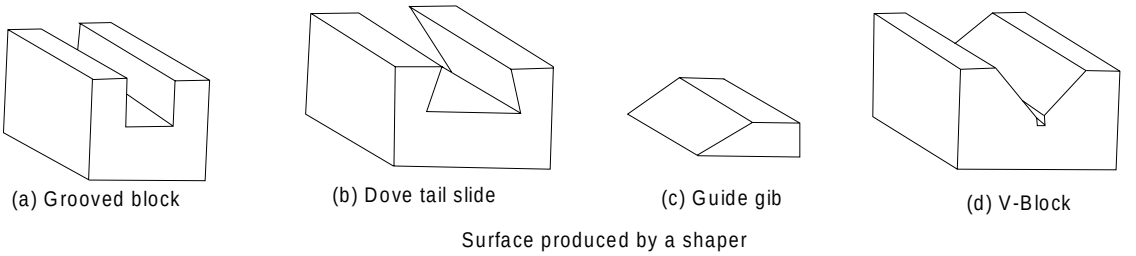


Fig. 23.3 Job surfaces generated by shaper

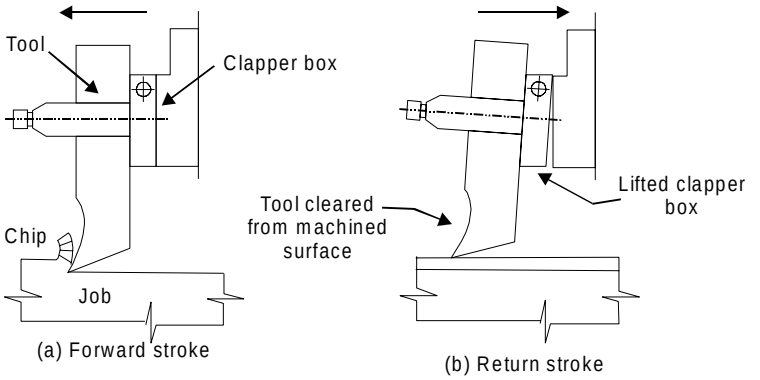


Fig. 23.4 Cutting action and functioning of clapper box

23.3 TYPES OF SHAPERS

Shapers are classified under the following headings:

(1) According to the type of mechanism used for giving reciprocating motion to the ram
   (*a*) Crank type
   (*b*) Geared type
   (*c*) Hydraulic type
(2) According to the type of design of the table:
   (*a*) Standard shaper
   (*b*) Universal shaper
(3) According to the position and travel of ram:
   (*a*) Horizontal type
   (*b*) Vertical type
   (*c*) Traveling head type
(4) According to the type of cutting stroke:
   (*a*) Push type
   (*b*) Draw type.

A brief description these shapers is given below-

23.3.1 Crank Shaper

This is the most common type of shaper. It employs a crank mechanism to change circular motion of a large gear called "bull gear" incorporated in the machine to reciprocating motion of the ram. The bull gear receives power either from an individual motor or from an overhead line shaft if it is a belt-driven shaper.

23.3.2 Geared Shaper

Geared shaper uses rack and pinion arrangement to obtain reciprocating motion of the ram. Presently this type of shaper is not very widely used.

23.3.3 Hydraulic Shaper

In hydraulic shaper, reciprocating motion of the ram is obtained by hydraulic power. For generation of hydraulic power, oil under high pressure is pumped into the operating cylinder fitted with piston. The piston end is connected to the ram through piston rod. The high pressure oil causes the piston to reciprocate and this reciprocating motion is transferred to the ram of shaper. The important advantage of this type of shaper is that the cutting speed and force of the ram drive are constant from the very beginning to the end of the cut.

23.3.4 Standard Shaper

In standard shaper, the table has only two movements, horizontal and vertical, to give the feed.

23.3.5 Universal Shaper

A universal shaper is mostly used in tool room work. In this type of shaper, in addition to the horizontal and vertical movements, the table can be swiveled about an axis parallel to

the ram ways, and the upper portion of the table can be tilted about a second horizontal axis perpendicular to the first axis.

23.3.6 Horizontal Shaper

In this type of shaper, the ram holding the tool reciprocates in a horizontal axis.

23.3.7 Vertical Shaper

In vertical shaper, the ram reciprocates in a vertical axis. These shapers are mainly used for machining keyways, slots or grooves, and internal surfaces.

23.3.8 Travelling Head Shaper

In this type of shaper, the ram while it reciprocates, also moves crosswise to give the required feed.

23.3.9 Push Type Shaper

This is the most general type of shaper used in common practice, in which the metal is removed when the ram moves away from the column, i.e. pushes the work.

23.3.10 Draw Type Shaper

In this type of shaper, the cutting of metal takes place when the ram moves towards the column of the machine, i.e. draws the work towards the machine. The tool is set in a reversed direction to that of a standard shaper.

23.4 PRINCIPAL PARTS OF SHAPER

Fig. 23.5 shows the parts of a standard shaper. The main parts are given as under.

1. Base
2. Column
3. Cross-rail
4. Saddle
5. Table
6. Ram
7. Tool head
8. Clapper box
9. Apron clamping bolt
10. Down feed hand wheel
11. Swivel base degree graduations
12. Position of stroke adjustment hand wheel
13. Ram block locking handle
14. Driving pulley
15. Feed disc
16. Pawl mechanism
17. Elevating screw

Some of important parts are discussed as under.

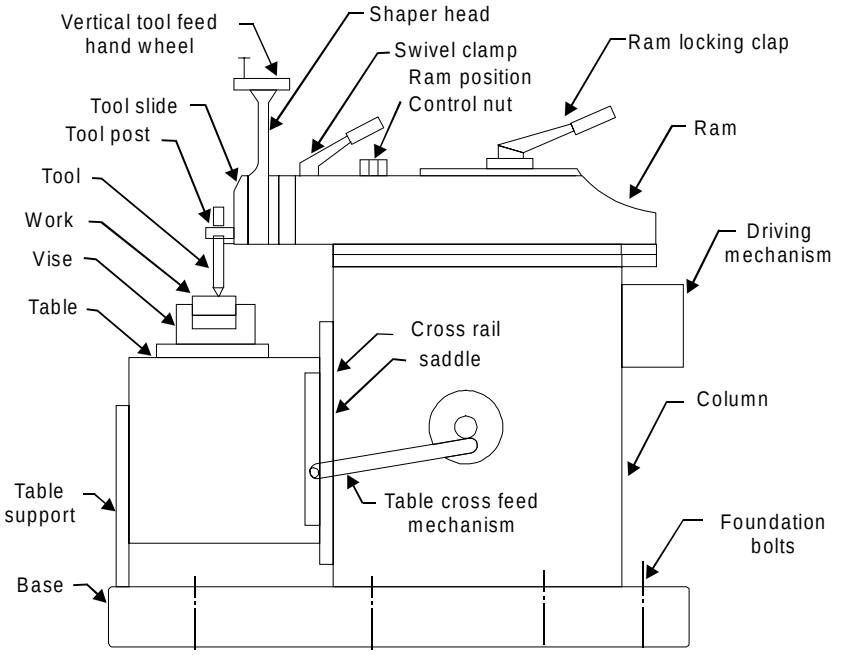


Fig. 23.5 Parts of a standard shaper

Base

It is rigid and heavy cast iron body to resist vibration and takes up high compressive load. It supports all other parts of the machine, which are mounted over it. The base may be rigidly bolted to the floor of the shop or on the bench according to the size of the machine.

Column

The column is a box shaped casting mounted upon the base. It houses the ram-driving mechanism. Two accurately machined guide ways are provided on the top of the column on which the ram reciprocates.

Cross rail

Cross rail of shaper has two parallel guide ways on its top in the vertical plane that is perpendicular to the rai1 axis. It is mounted on the front vertical guide ways of the column. It consists mechanism for raising and lowering the table to accommodate different sizes of jobs by rotating an elevating screw which causes the cross rail to slide up and down on the vertical face of the column. A horizontal cross feed screw is fitted within the cross rail and parallel to the top guide ways of the cross rail. This screw actuates the table to move in a crosswise direction.

Saddle

The saddle is located on the cross rail and holds the table on its top. Crosswise movement of the saddle by rotation the cross feed screw by hand or power causes the table to move sideways.

Table

The table is a box like casting having T -slots both on the top and sides for clamping the

work. It is bolted to the saddle and receives crosswise and vertical movements from the saddle and cross rail.

Ram

It is the reciprocating part of the shaper, which reciprocates on the guideways provided above the column. Ram is connected to the reciprocating mechanism contained within the column.

Tool head

The tool head of a shaper performs the following functions-

(1) It holds the tool rigidly,

(2) It provides vertical and angular feed movement of the tool, and

(3) It allows the tool to have an automatic relief during its return stroke.

The various parts of tool head of shaper are apron clamping bolt, clapper box, tool post, down feed, screw micrometer dial, down feed screw, vertical slide, apron washer, apron swivel pin, and swivel base. By rotating the down feed screw handle, the vertical slide carrying the tool gives down feed or angular feed movement while machining vertical or angular surface. The amount of feed or depth of cut may be adjusted by a micrometer dial on the top of the down feed screw. Apron consisting of clapper box, clapper block and tool post is clamped upon the vertical slide by a screw. The two vertical walls on the apron called clapper box houses the clapper block, which is connected to it by means of a hinge pin. The tool post is mounted upon the clapper block. On the forward cutting stroke the clapper block fits securely to the clapper box to make a rigid tool support. On the return stroke a slight frictional drag of the tool on the work lifts the block out of the clapper box a sufficient amount preventing the tool cutting edge from dragging and consequent wear. The work surface is also prevented from any damage due to dragging.

23.5 SPECIFICATION OF A SHAPER

The size of a shaper is specified by the maximum length of stroke or cut it can make. Usually the size of shaper ranges from 175 to 900 mm. Besides the length of stroke, other particulars, such as the type of drive (belt drive or individual motor drive), floor space required, weight of the machine, cutting to return stroke ratio, number and amount of feed, power input etc. are also sometimes required for complete specification of a shaper.

23.6 SHAPER MECHANISM

In a shaper, rotary motion of the drive is converted into reciprocating motion of the ram by the mechanism housed within the column or the machine. In a standard shaper metal is removed in the forward cutting stroke, while the return stroke goes idle and no metal is removed during this period as shown in Fig. 23.4. The shaper mechanism is so designed that it moves the ram holding the tool at a comparatively slower speed during forward cutting stroke, whereas during the return stroke it allow the ram to move at a faster speed to reduce the idle return time. This mechanism is known as quick return mechanism. The reciprocating movement of the ram and the quick return mechanism of the machine are generally obtained by anyone of the following methods:

(1) Crank and slotted link mechanism
(2) Whitworth quick return mechanism, and
(2) Hydraulic shaper mechanism

The crank and slotted link mechanism is discussed as under.

23.6.1 Crank and Slotted Link Mechanism

In crank and slotted link mechanism (Fig. 23.6), the pinion receives its motion from an individual motor or overhead line shaft and transmits the motion or power to the bull gear. Bull gear is a large gear mounted within the column. Speed of the bull gear may be changed by different combination of gearing or by simply shifting the belt on the step cone pulley. A radial slide is bolted to the centre of the bull gear. This radial slide carries a sliding block into which the crank pin is fitted. Rotation of the bull gear will cause the bush pin to revolve at a uniform speed. Sliding block, which is mounted upon the crank pin is fitted within the slotted link. This slotted link is also known as the rocker arm. It is pivoted at its bottom end attached to the frame of the column. The upper end of the rocker arm is forked and connected to the ram block by a pin. With the rotation of bull gear, crank pin will rotate on the crank pin circle, and simultaneously move up and down the slot in the slotted link giving it a rocking movement, which is communicated to the ram. Thus the rotary motion of the bull gear is converted to reciprocating motion of the ram.

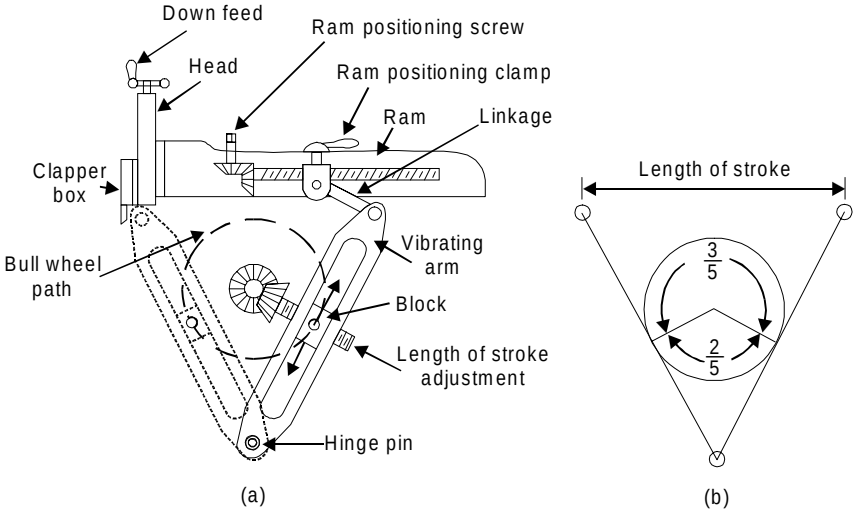


Fig. 23.6 Crank and slotted link mechanism

23.7 SURFACES PRODUCED ON SHAPER

1. Horizontal plain surface
2. Vertical plain surface
3. Inclined surface
4. Grooved surface
5. Slotted surface
6. Stepped surface

23.8 SHAPER OPERATIONS

A shaper is a machine tool primarily designed to generate a flat surface by a single point cutting tool. Besides this, it may also be used to perform many other operations. The different operations, which a shaper can perform, are as follows:

1. Machining horizontal surface (Fig. 23.7)
2. Machining vertical surface (Fig. 23.8)
3. Machining angular surface (Fig. 23.9)
4. Slot cutting (Fig. 23.10)
5. Key ways cutting (Fig. 23.11)
6. Machining irregular surface (Fig. 23.12)
7. Machining splines and cutting gears (Fig. 23.13)

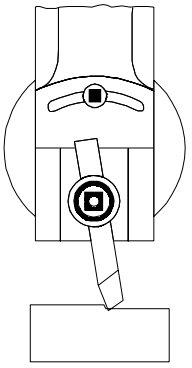


Fig. 23.7 Machining horizontal vertical surface on shaper

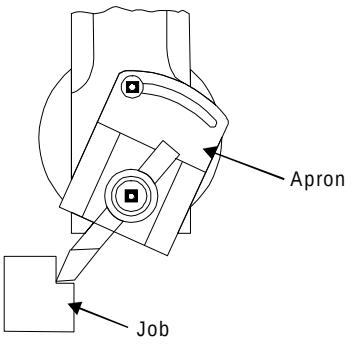
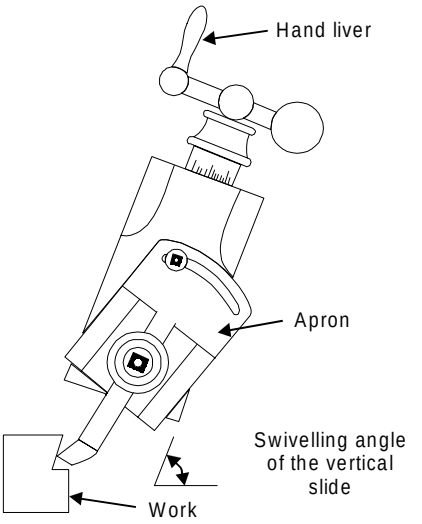
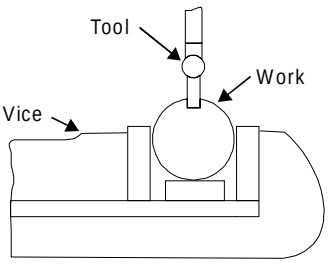


Fig. 23.8 Machining vertical surface on shaper



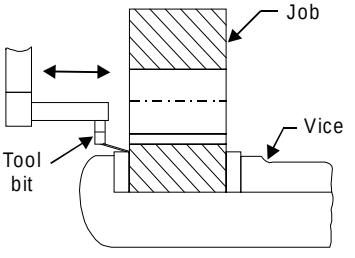
Cutting slots and keyways.

Fig. 23.9 Machining angular surface on shaper



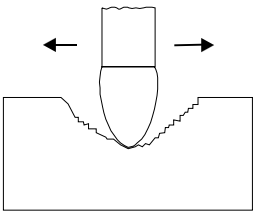
Slot cutting

Fig. 23.10 Slot cutting on shaper



Keyway cutting

Fig. 23.11 Keyway cutting on shaper



Irregular machining

Fig. 23.12 Machining irregular surface on shaper

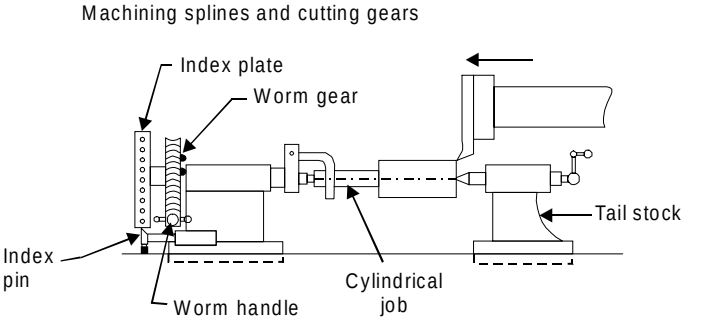


Fig. 23.13 Machining splines and cutting gears on shaper

23.9 PLANER

Like a shaper, planer is used primarily to produce horizontal, vertical or inclined flat surfaces by a single point cutting tool. But it is used for machining large and heavy work-pieces that cannot be accommodated on the table of a shaper. In addition to machining large work, the planer is frequently used to machine multiple small parts held in line on the platen. Planer is mainly of two kinds namely open housing planer and double housing planer. The principle parts of the open housing planer are shown in Fig 23.14(a). The principle parts of the double housing planer are shown in Fig 23.14(b). The bigger job is fixed with help of the grooves on the base of the planer and is accurately guided as it travels back and forth. Cutting tools are held in tool heads of double housing planer and the work piece is clamped onto the worktable as shown in Fig. 23.14(b). The worktable rides on the gin tool heads that can travel

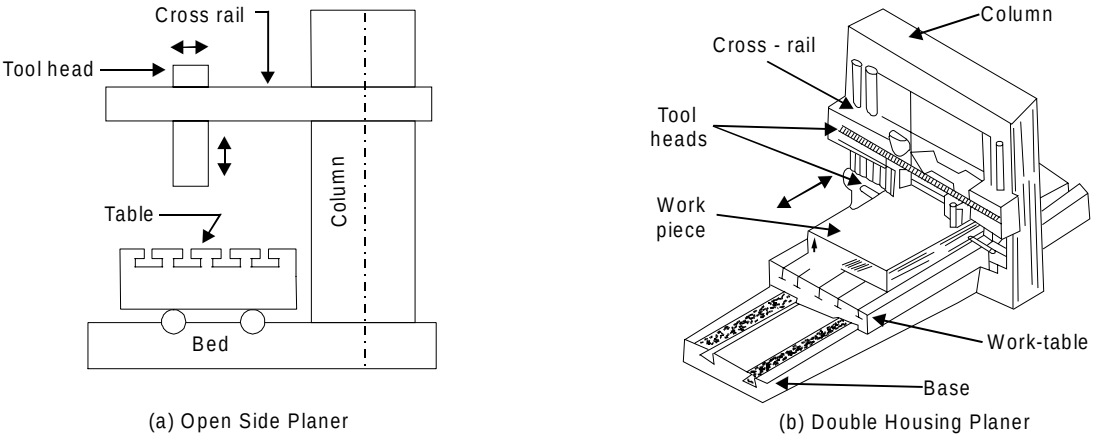


Fig. 23.14 Principle parts of double housing planer

from side to side i.e., in a direction at right angle to the direction of motion of the worktable. Tool heads are mounted on a horizontal cross rail that can be moved up and down. Cutting is achieved by applying the linear primary motion to the workpiece (motion X) and feeding the tool at right angles to this motion (motion Y and Z). The primary motion of the worktable is normally accomplished by a rack and pinion drive using a variable speed motor. As with the shaper, the tool posts are mounted on clapper boxes to prevent interference between the tools and work-piece on the return stroke and the feed motion is intermittent. The size of

a standard planer is specified by the size of the largest solid that can reciprocate under the tool. In addition to this, some other parameters such as table size (length and width), type of drive, number of speeds and feeds available, power input, weight of the machine, floor space required etc. may be required to specify a planer completely.

23.10 WORKING PRINCIPAL OF PLANER

Fig. 23.15 depicts the working principle of a planer. In a planer, the work which is supported on the table reciprocates past the stationary cutting tool and the feed is imparted by the lateral movement of the tool. The tool is clamped in the tool holder and work on the table. Like shaper, the planner is equipped with clapper box to raise the tool in idle stroke. The different mechanisms used to give reciprocating motion to the table are following-

1. Reversible motor drive
2. Open and cross belt drive
3. Hydraulic drive

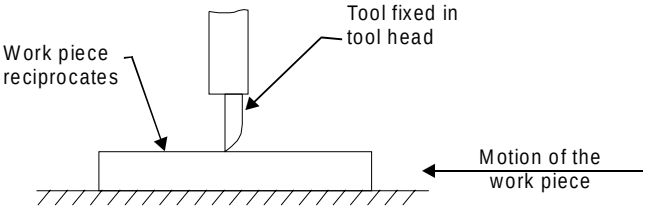


Fig. 23.15 Working principle of a planer

23.11 DIFFERENCE BETWEEN SHAPER AND PLANER

The difference between shaper and planner is given in Table 23.1.

Table 23.1 Difference between Shaper and Planer

S.No.	Shaper	Planer
1	The work is held stationary and the cutting tool on the ram is moved back and forth across the work	In a planer, the tool is stationary and the workpiece travels back and forth under the tool.
2	It is used for shaping much smaller jobs	A planer is meant for much larger jobs than can be undertaken on a shaper. Jobs as large as 6 metre wide and twice as long can be machined on a planer
3	A shaper is a light machine	It is a heavy duty machine.
4	Shaper can employ light cuts and finer feed	Planer can employ heavier cuts and coarse feed,
5	A shaper uses one cutting tool at a time	Several tools can cut simultaneously on a planer
6	The shaper is driven using quick-return link mechanism	The drive on the planer table is either by gears or by hydraulic means
7	It is less rigid and less robust	Because of better rigidity of planer, as compared to that of a shaper, planer can give more accuracy on machined surfaces.

23.12 TYPES OF PLANERS

Planers may be classified in a number of ways, but according to general construction, these are the following types:

1. Double housing planer
2. Open side planer
3. Pit planer
4. Edge or plate type planer
5. Divided table planer

23.13 SLOTTER

The slotter or slotting machine is also a reciprocating type of machine tool similar to a shaper or a planer. It may be considered as a vertical shaper. The chief difference between a shaper and a slotter is the direction of the cutting action. The machine operates in a manner similar to the shaper, however, the tool moves vertically rather than in a horizontal direction. The job is held stationary. The slotter has a vertical ram and a hand or power operated rotary table.

23.14 PRINCIPLE PARTS OF A SLOTTER

Fig. 23.16 shows a slotter and its various parts. The main parts of a slotter are discussed as under:

Bed or Base

It is made up of cast iron. It supports column, tables, ram, driving mechanism etc. The top of the bed carries horizontal ways along which the worktable can traverse.

Table

It holds the work piece and is adjustable in longitudinal and cross-wise directions. The table can be rotated about its centre.

Hand wheels

They are provided for rotating the table and for longitudinal and cross traverse.

Column is the vertical member

They are made up of cast iron and it houses the driving mechanism. The vertical front face of the column is accurately finished for providing ways along which the ram moves up and down.

Ram

It is provided to reciprocate vertically up and down. At its bottom, it carries the cutting tool. It is similar to the ram of a shaper; but it is more massive and moves vertically, at right angle to the worktable, instead of having the horizontal motion of a shaper:

Cross-slide

It can be moved parallel to the face of the column. The circular work-table is mounted on the top of the cross-slide.

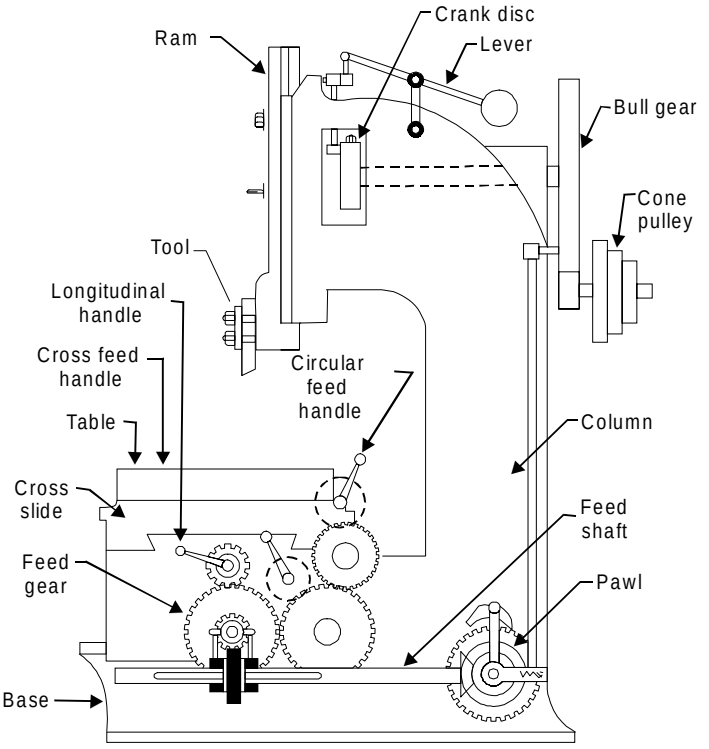


Fig. 23.16 Slotter and its various parts

23.15 OPERATIONS PERFORMED ON A SLOTTING MACHINE

A slotter is a very economical machine tool when used for certain classes of work given as under.

(*i*) It is used for machining vertical surfaces

(*ii*) It is used angular or inclined surfaces

(*iii*) It is used It is used to cut slots, splines keyways for both internal and external jobs such as machining internal and external gears,

(*iv*) It is used for works as machining concave, circular, semi-circular and convex surfaces

(*v*) It is used for shaping internal and external forms or profiles

(*vi*) It is used for machining of shapes which are difficult to produce on shaper

(*vii*) It is used for internal machining of blind holes

(*viii*) It is used for machining dies and punches, and

Since a slotter works slowly. It has less use in mass production work. It can be substituted by the broaching machine.

23.16 QUESTIONS

1. Explain principal parts of a shaper by neat sketch.
2. How can you classify the shapers?

3. How can you specify a shaper?
4. Explain the principle of quick return motion mechanism of a shaper. What is need of this mechanism?
5. Using neat sketches, describe the various operations that can be carried on shaping machines.
6. Explain various safety precautions associated with shaper.
7. Explain principal parts of a planer by neat sketches.
8. State the working principle of a planer.
9. Using neat sketch show the various parts of a planer.
10. Classify planers? Explain the universal planer.
11. Show by neat sketches various types of planer tools.
12. How table reversal is obtained in a planer?
13. Using neat sketches, describe the various operations that can be carried on planer.
14. Make neat sketch of a slotter. Explain its working with applications.
15. Differentiate between shaper, planer and slotter.

24 CHAPTER

MILLING

24.1 INTRODUCTION

A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. The milling cutter rotates at high speed and it removes metal at a very fast rate with the help of multiple cutting edges. One or more number of cutters can be mounted simultaneously on the arbor of milling machine. This is the reason that a milling machine finds wide application in production work. Milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads, and helical surfaces of various cross-sections. Typical components produced by a milling are given in Fig. 24.1. In many applications, due to its higher production rate and accuracy, milling machine has even replaced shapers and slotters.

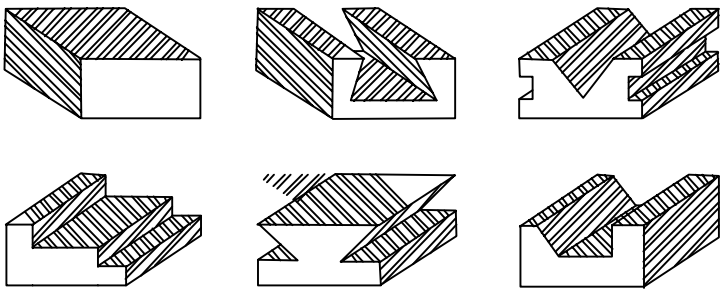


Fig. 24.1 Job surfaces generated by milling machine

24.2 PRINCIPLE OF MILLING

In milling machine, the metal is cut by means of a rotating cutter having multiple cutting edges. For cutting operation, the workpiece is fed against the rotary cutter. As the workpiece moves against the cutting edges of milling cutter, metal is removed in form chips of trochoid shape. Machined surface is formed in one or more passes of the work. The work to be machined is held in a vice, a rotary table, a three jaw chuck, an index head, between centers, in a special fixture or bolted to machine table. The rotatory speed of the cutting tool and the feed rate of the workpiece depend upon the type of material being machined.

24.3 MILLING METHODS

There are two distinct methods of milling classified as follows:

1. Up-milling or conventional milling, and
2. Down milling or climb milling.

24.3.1 UP-Milling or Conventional Milling Procedure

In the up-milling or conventional milling, as shown in Fig. 24.2, the metal is removed in form of small chips by a cutter rotating against the direction of travel of the workpiece. In this type of milling, the chip thickness is minimum at the start of the cut and maximum at the end of cut. As a result the cutting force also varies from zero to the maximum value per tooth movement of the milling cutter. The major disadvantages of up-milling process are the tendency of cutting force to lift the work from the fixtures and poor surface finish obtained. But being a safer process, it is commonly used method of milling.

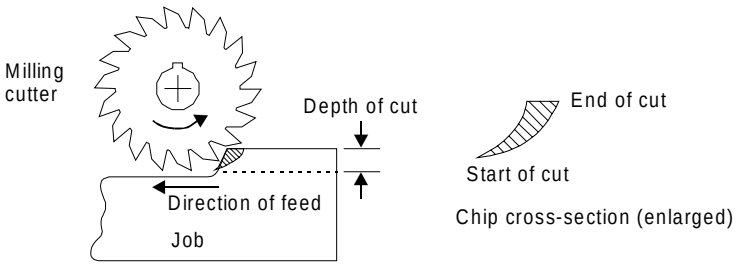


Fig. 24.2 Principal of up-milling

24.3.2 Down-Milling or Climb Milling

Down milling is shown in Fig. 24.3. It is also known as climb milling. In this method, the metal is removed by a cutter rotating in the same direction of feed of the workpiece. The effect of this is that the teeth cut downward instead of upwards. Chip thickness is maximum at the start of the cut and minimum in the end. In this method, it is claimed that there is less friction involved and consequently less heat is generated on the contact surface of the cutter and workpiece. Climb milling can be used advantageously on many kinds of work to increase the number of pieces per sharpening and to produce a better finish. With climb milling, saws cut long thin slots more satisfactorily than with standard milling. Another advantage is that slightly lower power consumption is obtainable by climb milling, since there is no need to drive the table against the cutter.

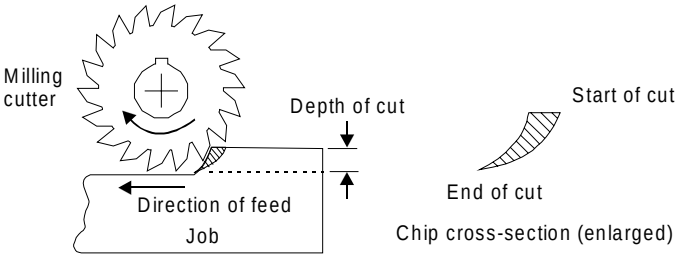


Fig. 24.3 Principal of down-milling

24.4 TYPES OF MILLING CUTTERS

Fig. 24.4 illustrates some types of milling cutters along with workpieces. Milling cutters are made in various forms to perform certain classes of work, and they may be classified as:

(1) Plain milling cutters,
(2) Side milling cutters,
(3) Face milling cutter,
(4) Angle milling cutters,
(5) End milling cutter,
(6) Fly cutter,
(7) T-slot milling cutter,
(8) Formed cutters,
(9) Metal slitting saw,

Milling cutters may have teeth on the periphery or ends only, or on both the periphery and ends. Peripheral teeth may be straight or parallel to the cutter axis, or they may be helical, sometimes referred as spiral teeth.

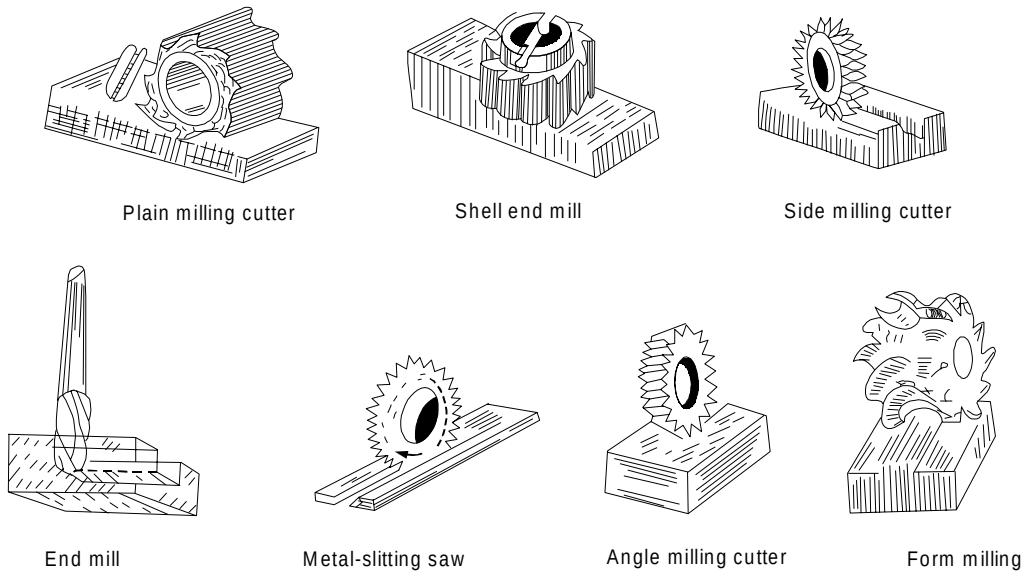


Fig. 24.4 Types of milling cutters

24.5 TYPES OF MILLING MACHINES

Milling machine rotates the cutter mounted on the arbor of the machine and at the same time automatically feed the work in the required direction. The milling machine may be classified in several forms, but the choice of any particular machine is determined primarily by the size of the workpiece to be undertaken and operations to be performed. With the above function or requirement in mind, milling machines are made in a variety of types and sizes. According to general design, the distinctive types of milling machines are:

1. Column and knee type milling machines
   (*a*) Hand milling machine
   (*b*) Horizontal milling machine (Fig. 24.5)
   (*c*) Universal milling machine
   (*d*) Vertical milling machine (Fig. 24.6)

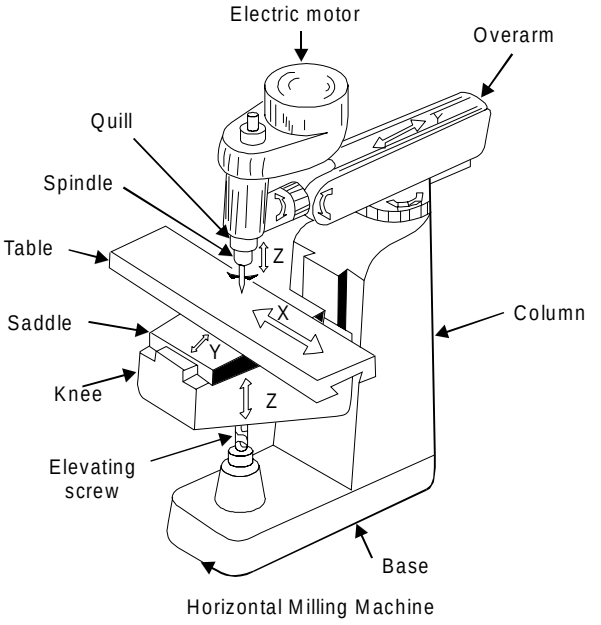


Fig. 24.5 Horizontal column and knee type milling machine

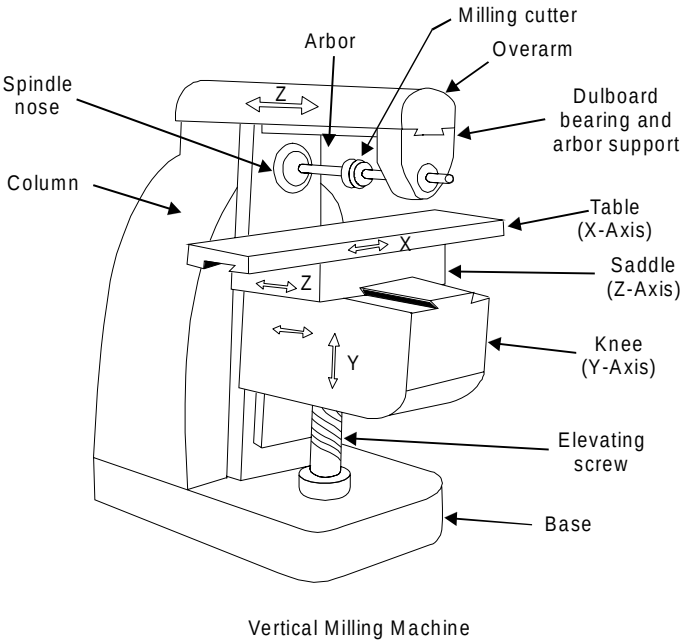


Fig. 24.6 Vertical column and knee type milling machine

2. Planer milling machine
3. Fixed-bed type milling machine
   (*a*) Simplex milling machine.
   (*b*) Duplex milling machine.
   (*c*) Triplex milling machine.
4. Machining center machines
5. Special types of milling machines
   (*a*) Rotary table milling machine.
   (*b*) Planetary milling machine.
   (*c*) Profiling machine.
   (*d*) Duplicating machine.
   (*e*) Pantograph milling machine.
   (*f*) Continuous milling machine.
   (*g*) Drum milling machine
   (*h*) Profiling and tracer controlled milling machine

Some important types of milling machines are discussed as under.

24.5.1 Column and Knee Type Milling Machine

Fig. 24.7 shows a simple column and knee type milling machine. It is the most commonly used milling machine used for general shop work. In this type of milling machine the table

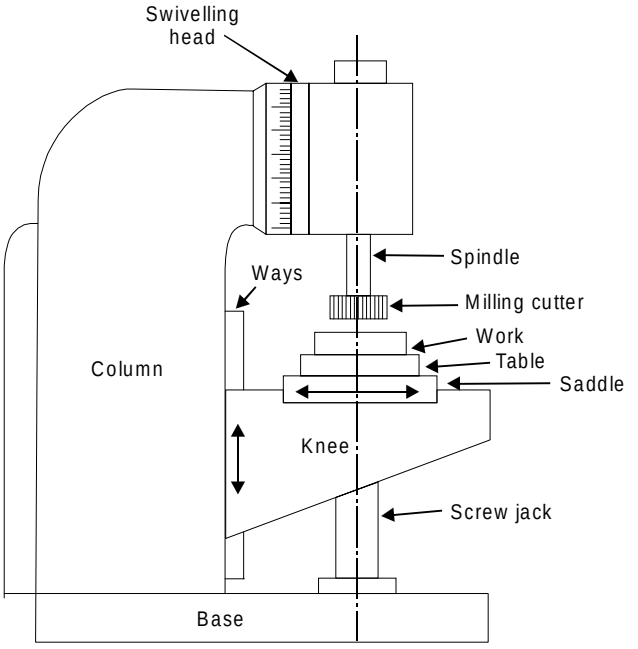


Fig. 24.7 A column and knee type milling machine

is mounted on the knee casting which in turn is mounted on the vertical slides of the main column. The knee is vertically adjustable on the column so that the table can be moved up and down to accommodate work of various heights. The column and knee type milling machines are classified on the basis of various methods of supplying power to the table, different movements of the table and different axis of rotation of the main spindle. Column and knee type milling machine comprises of the following important parts-

1. Base
2. Column
3. Saddle
4. Table
5. Elevating screw
6. Knee
7. Knee elevating handle
8. Cross feed handle
9. Front brace
10. Arbor support
11. Arbor
12. Overhanging arm
13. Cutter
14. Cone pulley
15. Telescopic feed shaft.

The principal parts of a column and knee type milling machine are described as under.

Base

It is a foundation member for all the other parts, which rest upon it. It carries the column at its one end. In some machines, the base is hollow and serves as a reservoir for cutting fluid.

Column

The column is the main supporting member mounted vertically on the base. It is box shaped, heavily ribbed inside and houses all the driving mechanism for the spindle and table feed. The front vertical face of the column is accurately machined and is provided with dovetail guideway for supporting the knee.

Knee

The knee is a rigid grey iron casting which slides up and down on the vertical ways of the column face. An elevating screw mounted on the base is used to adjust the height of the knee and it also supports the knee. The knee houses the feed mechanism of the table, and different controls to operate it.

Saddle

The saddle is placed on the top of the knee and it slides on guideways set exactly at 90° to the column face. The top of the saddle provides guide-ways for the table.

Table

The table rests on ways on the saddle and travels longitudinally. A lead screw under the table engages a nut on the saddle to move the table horizontally by hand or power. In universal machines, the table may also be swiveled horizontally. For this purpose the table is mounted on a circular base. The top of the table is accurately finished and T -slots are provided for clamping the work and other fixtures on it

Overhanging arm

It is mounted on the top of the column, which extends beyond the column face and serves as a bearing support for the other end of the arbor.

Front brace

It is an extra support, which is fitted between the knee and the over-arm to ensure further rigidity to the arbor and the knee.

Spindle

It is situated in the upper part of the column and receives power from the motor through belts, gears. and clutches and transmit it to the arbor.

Arbor

It is like an extension of the machine spindle on which milling cutters are securely mounted and rotated. The arbors are made with taper shanks for proper alignment with the machine spindles having taper holes at their nose. The draw bolt is used for managing for locking the arbor with the spindle and the whole assembly. The arbor assembly consists of the following components.

1. Arbor
2. Spindle
3. Spacing collars
4. Bearing bush
5. Cutter
6. Draw bolt
7. Lock nut
8. Key block
9. Set screw

24.5.2 Planer Type Milling Machine

It is a heavy duty milling machine. It resembles a planer and like a planning machine it has a cross rail capable of being raised or lowered carrying the cutters, their heads, and the saddles, all supported by rigid uprights. There may be a number of independent spindles carrying cutters on the rail as two heads on the uprights. The use of the machine is limited to production work only and is considered ultimate in metal re-moving capacity.

24.5.3 Special Type Milling Machines

Milling machines of non-conventional design have been developed to suit special purposes. The features that they have in common are the spindle for rotating the cutter and provision for moving the tool or the work in different directions.

24.6 SIZE OF MILLING MACHINE

The size of the column and knee type milling machine is specified by

(1) The dimensions of the working surface of the table, and

(2) Its maximum length of longitudinal, cross and vertical travel of the table.

In addition to above, number of spindle speeds, number of feeds, spindle nose taper, power available, floor space required and net weight of machine will also be required for additional specification.

24.7 DEPTH OF CUT

The depth of cut in milling is defined as the thickness of the material removed in one pass of the work under the cutter. Thus it is the perpendicular distance measured between the original and final surface of the workpiece, and is expressed in mm.

24.8 INDEXING AND DIVIDING HEADS

Indexing is the operation of dividing the periphery of a piece of work into any number of equal parts. In cutting spur gear equal spacing of teeth on the gear blank is performed by indexing. Indexing is accomplished by using a special attachment known as dividing head or index head as shown in Fig. 24.8. The dividing heads are of three types:

(1) Plain or simple dividing head,

(2) Universal dividing head and

(3) Optical dividing head.

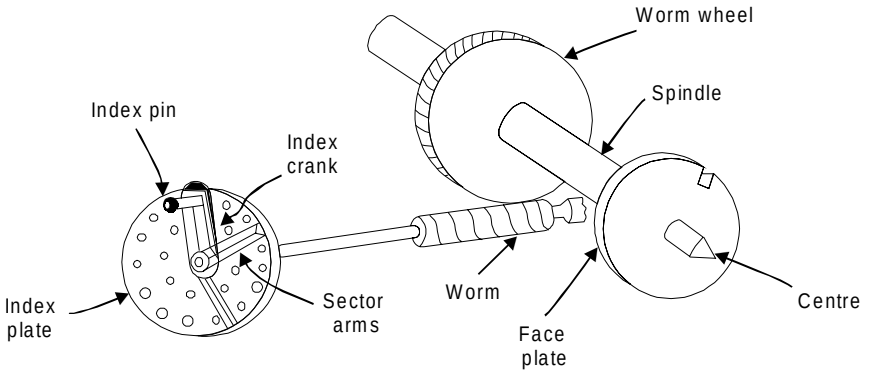


Fig. 24.8 Dividing head

24.8.1 Plain or Simple Dividing Head

The plain dividing head comprises a cylindrical spindle housed on a frame, and a base bolted to the machine table. The index crank is connected to the tail end of the spindle directly, and the crank and the spindle rotate as one unit. The index plate is mounted on the spindle and rotates with it. The spindle may be rotated through the desired angle and then clamped by inserting the clamping lever pin into anyone of the equally spaced holes or slots cut on the periphery of the index plate. This type of dividing head is used for handling large number of workpieces, which require a very small number of divisions on the periphery.

1. Swiveling block
2. Live centre
3. Index crank
4. Index plate.

24.9 OPERATIONS PERFORMED ON MILLING MACHINE

Unlike a lathe, a milling cutter does not give a continuous cut, but begins with a sliding motion between the cutter and the work. Then follows a crushing movement, and then a cutting operation by which the chip is removed. Many different kinds of operations can be performed on a milling machine but a few of the more common operations will now be explained. These are:

Plain milling or slab milling

Fig. 24.9(a) illustrates the plain and slab milling operation. It is a method of producing a plain, flat, horizontal surface parallel to the axis of rotation of the cutter.

Face milling

Fig. 24.9(b) illustrates the face milling operation. It is a method of producing a flat surface at right angles to the axis of the cutter.

Side milling

Fig. 24.9(c) illustrates the side milling operation. It is the operation of production of a flat vertical surface on the side of a work-piece by using a side milling cutter.

Angular milling

Fig. 24.9(d) illustrates angular milling operation. It is a method of producing a flat surface making an angle to the axis of the cutter.

Gang-milling

Fig. 24.9(e) illustrates the gang milling operation. It is a method of milling by means of two or more cutters simultaneously having same or different diameters mounted on the arbor of the milling machine.

Form milling

Fig. 24.9(f) illustrates the form milling operation. It is, a method of producing a surface having an irregular outline.

End milling

Fig. 24.9(g) illustrates end milling operation. It is a method of milling slots, flat surfaces, and profiles by end mills.

Profile milling

Fig. 24.9(h) illustrates profile milling operation. It is the operation of reproduction of an outline of a template or complex shape of a master die on a workpiece.

Saw milling

Fig. 24.9(i) illustrates saw milling operation. It is a method of producing deep slots and cutting materials into the required length by slitting saws.

T-slot milling

Fig. 24.9(j) illustrates T-slot milling operation.

Keyway milling

Fig. 24.9(k) illustrates keyway milling operation.

Gear cutting milling

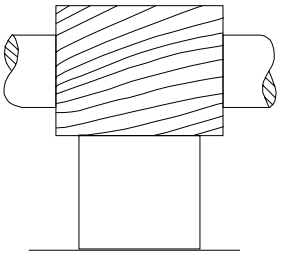
Fig. 24.9(l) illustrates gear cutting milling operation.

Helical milling

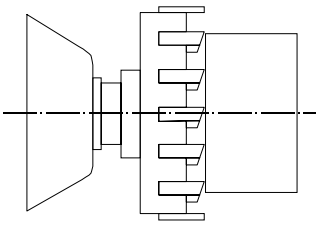
Fig. 24.9(m) illustrates helical milling operation.

Flute milling

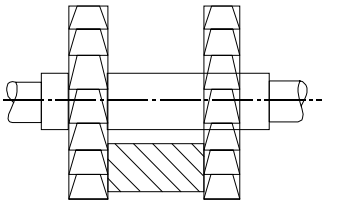
It is a method of grooving or cutting of flutes on drills, reamers, taps, etc,



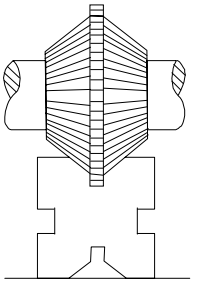
(a) Plane milling



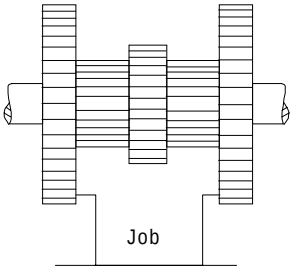
(b) Face milling



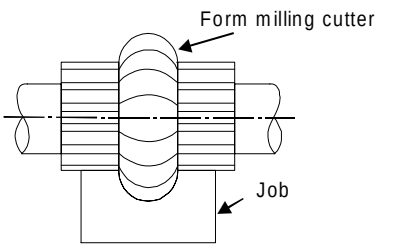
(c) Side milling



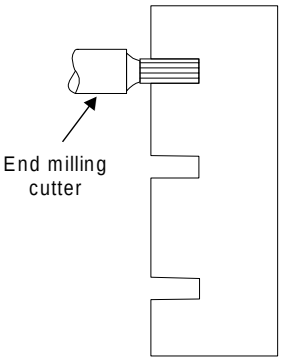
(d) Angular milling



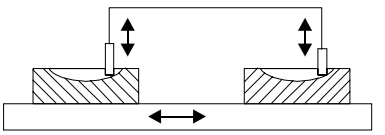
(e) Gang milling



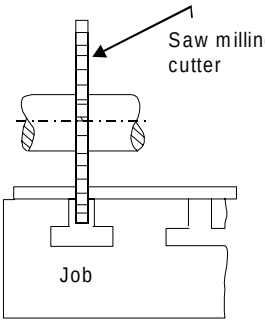
(f) Form Milling



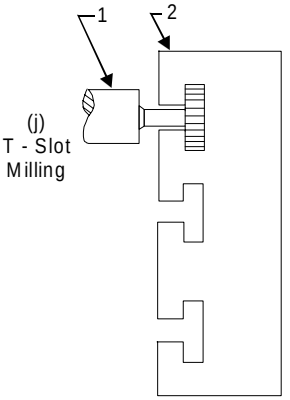
(g) End milling

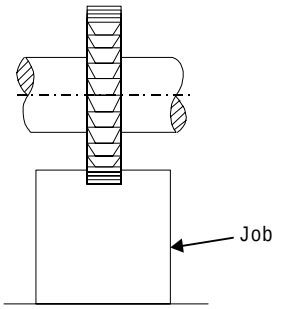


(h) Profile milling

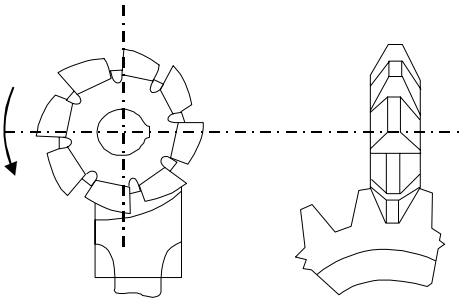


(i) Saw milling





(k) Key way milling



(l) Gear Cutting Milling

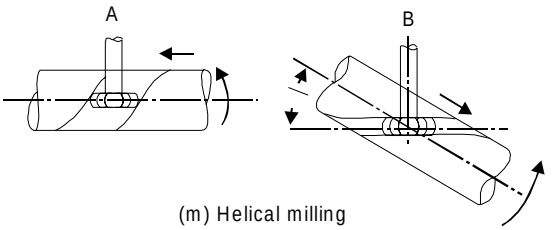


Fig. 24.9 Various types of milling operations

Straddle milling

It is a method of milling two sides of a piece of work by employing two side-milling cutters at the same time.

Thread milling

It is a method of milling threads on dies, screws, worms, etc. both internally and externally. As an alternative to the screw cutting in a lathe, this method is being more extensively introduced now a day in modern machine shops.

24.10 QUESTIONS

1. State the working principle of milling machine.
2. How will you classify milling machines?
3. Using neat sketch, describe the principal parts of the milling machine by neat sketches.
4. Differentiate between up milling and down milling.
5. With the help of a neat sketch explain the column and knee type milling machine and name its main parts.
6. Explain various types of milling operations using neat sketches.
7. Describe thread milling.
8. Sketch and describe the indexing head used for gear cutting.
9. Explain the principle of differential indexing.
10. What is indexing? Describe direct indexing, with example.
11. Single angle milling cutter (*b*) Slot milling cutter (*d*) Convex milling cutter.
12. How will you index the gear teeth? Sketch the indexing set-up showing necessary calculations.
13. Sketch the machining set-up indicating tool work motions.
14. Sketch and specify the milling cutter indicating important tool geometry.
15. Define the following terms used in milling operation.
    (*a*) Cutting speed
    (*b*) Feed
    (*c*) Depth of cut
    (*d*) Machining time.

25
CHAPTER

POWDER METALLURGY

25.1 INTRODUCTION

Powder metallurgy is used for manufacturing products or articles from powdered metals by placing these powders in molds and are compacting the same using heavy compressive force. Typical examples of such article or products are grinding wheels, filament wire, magnets, welding rods, tungsten carbide cutting tools, self-lubricating bearings electrical contacts and turbines blades having high temperature strength. The manufacture of parts by powder metallurgy process involves the manufacture of powders, blending, compacting, profiteering, sintering and a number of secondary operations such as sizing, coining, machining, impregnation, infiltration, plating, and heat treatment. The compressed articles are then heated to temperatures much below their melting points to bind the particles together and improve their strength and other properties. Few non-metallic materials can also be added to the metallic powders to provide adequate bond or impart some the needed properties. The products made through this process are very costly on account of the high cost of metal powders as well as of the dies used. The powders of almost all metals and a large quantity of alloys, and nonmetals may be used. The application of powder metallurgy process is economically feasible only for high mass production. Parts made by powder metallurgy process exhibit properties, which cannot be produced by conventional methods. Simple shaped parts can be made to size with high precision without waste, and completely or almost ready for installation.

25.2 POWDER METALLURGY PROCESS

The powder metallurgy process consists of the following basic steps:

1. Formation of metallic powders.
2. Mixing or blending of the metallic powders in required proportions.
3. Compressing and compacting the powders into desired shapes and sizes in form of articles.
4. Sintering the compacted articles in a controlled furnace atmosphere.
5. Subjecting the sintered articles to secondary processing if needed so.

25.2.1 Production of Metal Powders

Metallic powders possessing different properties can be produced easily. The most commonly used powders are copper-base and iron-base materials. But titanium, chromium, nickel, and stainless steel metal powders are also used. In the majority of powders, the size of the particle varies from several microns to 0.5 mm. The most common particle size of powders falls into a range of 10 to 40 microns. The chemical and physical properties of metals depend upon the size and shape of the powder particles. There are various methods of manufacturing powders.The commonly used powder making processes are given as under.

1. Atomization
2. Chemical reduction
3. Electrolytic process
4. Crushing
5. Milling
6. Condensation of metal vapors
7. Hydride and carbonyl processes.

The above mentioned metallic powder making techniques are discussed briefly as under.

1. Atomization

In this process, the molten metal is forced through an orifice and as it emerges, a high pressure stream of gas or liquid impinges on it causing it to atomize into fine particles. The inert gas is then employed in order to improve the purity of the powder. It is used mostly for low melting point metals such as tin, zinc, lead, aluminium, cadmium etc., because of the corrosive action of the metal on the orifice (or nozzle) at high temperatures. Alloy powders are also produced by this method.

2. Chemical Reduction Process

In this process, the compounds of metals such as iron oxides are reduced with CO or H_2 at temperatures below the melting point of the metal in an atmosphere controlled furnace. The reduced product is then crushed and ground. Iron powder is produced in this way

$$Fe_3O_4 + 4C = 3Fe + 4CO$$

$$Fe_3O_4 + 4CO = 3Fe + 4CO_2$$

Copper powder is also produced by the same procedure by heating copper oxide in a stream of hydrogen.

$$Cu_2 + H_2 = 2Cu + H_2O$$

Powders of W, Mo, Ni and CO can easily be produced or manufactured by reduction process because it is convenient, economical and flexible technique and perhaps the largest volume of metallurgy powders is made by the process of oxide reduction.

3. Electrolytic Process

Electrolysis process is quite similar to electroplating and is principally employed for the production of extremely pure, powders of copper and iron. For making copper powder, copper plates are placed as anodes in a tank of electrolyte, whereas, aluminium plates are placed in to the electrolyte to act as cathodes. High amperage produces a powdery deposit of anode metal on the cathodes. After a definite time period, the cathode plates are taken out from the

tank, rinsed to remove electrolyte and are then dried. The copper deposited on the cathode plates is then scraped off and pulverized to produce copper powder of the desired grain size. The electrolytic powder is quite resistant to oxidation.

4. Crushing Process

The crushing process requires equipments such as stamps, crushers or gyratory crushes. Various ferrous and non-ferrous alloys can be heat-treated in order to obtain a sufficiently brittle material which can be easily crushed into powder form.

5. Milling Process

The milling process is commonly used for production of metallic powder. It is carried out by using equipments such as ball mill, impact mill, eddy mill, disk mill, vortex mill, etc. Milling and grinding process can easily be employed for brittle, tougher, malleable, ductile and harder metals to pulverize them. A ball mill is a horizontal barrel shaped container holding a quantity of balls, which, being free to tumble about as the container rotates, crush and abrade any powder particles that are introduced into the container. Generally, a large mass to be powdered, first of all, goes through heavy crushing machines, then through crushing rolls and finally through a ball mill to produce successively finer grades of powder.

6. Condensation of Metal Powders

This process can be applied in case of metals, such as Zn, Cd and Mg, which can be boiled and the vapors are condensed in a powder form. Generally a rod of metal say Zn is fed into a high temperature flame and vaporized droplets of metal are then allowed to condense on to a cool surface of a material to which they will not adhere. This method is not highly suitable for large scale production of powder.

7. Hydride and Carbonyl Processes

High hardness oriented metals such as tantalum, niobium and zirconium are made to combine with hydrogen form hydrides that are stable at room temperature, but to begin to dissociate into hydrogen and the pure metal when heated to about 350°C. Similarly nickel and iron can be made to combine with CO to form volatile carbonyls. The carbonyl vapor is then decomposed in a cooled chamber so that almost spherical particles of very pure metals are deposited.

25.2.2 Characteristic of Metal Powders

The performance of powder metallurgical parts is totally dependent upon the characteristics of metal powders. Most important characteristics of metal powders are powder particle size, size distribution, particle shape, purity, chemical composition, flow characteristics and particle microstructure. Some of the important properties are discussed as under.

Powder particle size and size distribution

Particle size of metal powder is expressed by the diameter for spherical shaped particles and by the average diameter for non-spherical particle as determined by sieving method or microscopic examination. Metal powders used in powder metallurgy usually vary in size from 20 to 200 microns. Particle size influences density/porosity of the compact, mold strength, permeability, flow and mixing characteristics, dimensional stability, etc. Particle size distribution is specified in terms of a sieve analysis i.e. the amount of powder passing through 20 or 40 mesh sieves.

Particle shape

There are various shapes of metal powders namely spherical, sub-rounded, rounded, angular, sub-angular, flakes etc. Particles shape influences the packing and flow characteristics of the powders.

Chemical composition

Chemical composition of metallic powder implies the type and percentage of alloying elements and impurities. It usually determines the particle hardness and compressibility. The chemical composition of a powder can be determined by chemical analysis methods.

Particle microstructure

Particle microstructure reveals various phases, inclusions and internal porosity.

Apparent density

Apparent density is defined as the weight, of a loosely heated quantity of powder necessary to fill a given die cavity completely.

Flow characteristics

Flow-ability of metal powders is most important in cases where moulds have to be filled quickly. Metal powders with good flow characteristics fill a mould cavity uniformly.

25.2.3 Mixing or Blending of Metallic Powders

After the formation of metallic powders, proper mixing or blending of powders is the first step in the forming of powder metal parts. The mixing is being carried out either wet or dry using an efficient mixer to produce a homogeneous mixture.

25.2.4 Compacting of Powder

Compacting is the technique of converting loose powder in to compact accurately defined shape and size. This is carried out at room temperature in a die on press machine. The press used for compacting may be either mechanically or hydraulically operated. The die consists of a cavity of the shape of the desired part. Metal powder is poured in the die cavity and pressure is applied using punches, which usually work from the top and bottom of the die as shown in Fig 25.1. Dies are usually made of high grade steel, but sometimes carbide dies are used for long production runs. In compacting process, the pressure applied should be uniform and applied simultaneously from above and below. The pressure applied should be high enough to produce cold welding of the powder. Cold welding imparts a green strength, which holds the parts together and allows them to be handled.

The metal parts obtained after compacting are not strong and dense. To improve these properties, the parts should be sintered.

25.2.5 Sintering

Sintering is the process of heating of compacted products in a furnace to below the melting point of at least one of the major constituents under a controlled atmosphere. The sintering temperature and time vary with the following factors-

1. Type of metal powder
2. Compressive load used, and
3. Strength requirements of the finished parts.

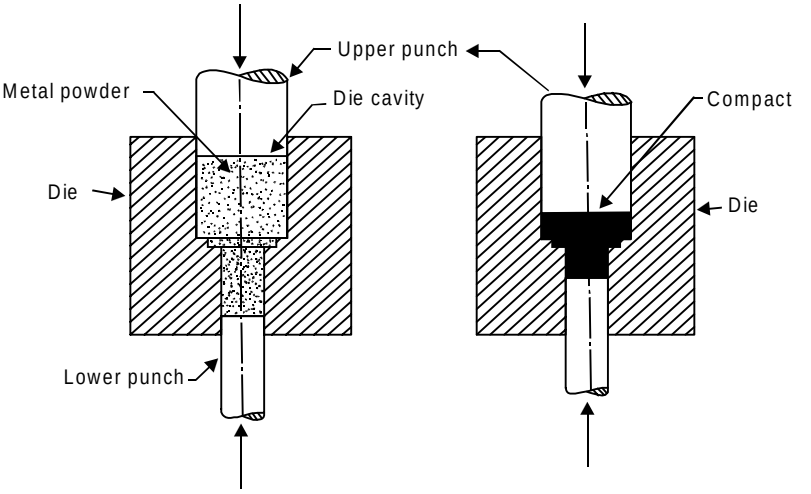


Fig. 25.1 Powder metallurgy die setup

In the sintering furnace, the metal parts are gradually heated and soaked at the required temperature. During this gradually heating process, powders bond themselves into coherent bodies. Sintering results in strengthening of fragile green compacts produced by the pressing operation. It also increases electrical conductivity, density and ductility of the powder metal parts.

25.2.6 Secondary Operations

Some powder metal parts may be used in the sintered condition while in some other cases additional secondary operations have to be performed to get the desired surface finish, close tolerance etc.. The secondary operations may be of following types-

1. Annealing.
2. Repressing for greater density or closer dimensional control.
3. Machining.
4. Polishing.
5. Rolling, forging or drawing.
6. Surface treatments to protect against corrosion.
7. In some cases infiltration is needed to provide increased strength, hardness, density obtainable by straight sintering.
8. The procedures for plating powdered metal parts are quite different from those used for wrought or cast metal parts. In powdered metal parts, porosity must be eliminated before the part is plated. After the porosity has been eliminated regular plating procedures can be used.

25.3 ADVANTAGES OF POWDER METALLURGY

1. The processes of powder metallurgy are quite and clean.
2. Articles of any intricate or complicated shape can be manufactured.

3. The dimensional accuracy and surface finish obtainable are much better for many applications and hence machining can be eliminated.
4. Unlike casting, press forming machining, no material is being wasted as scrap and the process makes utilizes full raw material
5. Hard to process materials such as diamond can be converted into usable components and tools through this process.
6. High production rates can be easily achieved.
7. The phase diagram constraints, which do not allow an alloy formation between mutually insoluble constituents in liquid state, such as in case of copper and lead are removed in this process and mixtures of such metal powders can be easily processed and shaped through this process.
8. This process facilitates production of many such parts, which cannot be produced through other methods, such as sintered carbides and self-lubricating bearings.
9. The process enables an effective control over several properties such as purity, density, porosity, particle size, etc., in the parts produced through this process.
10. The components produced by this process are highly pure and bears longer life.
11. It enables production of parts from such alloys, which possess poor cast ability.
12. It is possible to ensure uniformity of composition, since exact proportions of constituent metal powders can be used.
13. The preparation and processing of powdered iron and nonferrous parts made in this way exhibit good properties, which cannot be produced in any other way.
14. Simple shaped parts can be made to size with 100 micron accuracy without waste
15. Porous parts can be produced that could not be made in any other way.
16. Parts with wide variations in compositions and materials can be produced.
17. Structure and properties can be controlled more closely than in other fabricating processes.
18. Highly qualified or skilled labor is not required. in powder metallurgy process
19. Super-hard cutting tool bits, which are impossible to produce by other manufacturing processes, can be easily manufactured using this process.
20. Components shapes obtained possess excellent reproducibility.
21. Control of grain size, relatively much uniform structure and defect such voids and blowholes in structure can be eliminated.

25.4 LIMITATIONS OF POWDER METALLURGY

1. Powder metallurgy process is not economical for small-scale production.
2. The cost of tool and die of powder metallurgical set-up is relatively high
3. The size of products as compared to casting is limited because of the requirement of large presses and expensive tools which would be required for compacting.
4. Metal powders are expensive and in some cases difficult to store without some deterioration.

5. Intricate or complex shapes produced by casting cannot be made by powder metallurgy because metallic powders lack the ability to flow to the extent of molten metals.
6. Articles made by powder metallurgy in most cases do not have as good physical properties as wrought or cast parts.
7. It may be difficult sometimes to obtain particular alloy powders
8. Parts pressed from the top tend to be less dense at the bottom.
9. A completely deep structure cannot be produced through this process.
10. The process is not found economical for small-scale production.
11. It is not easy to convert brass, bronze and a numbers of steels into powdered form.

25.5 APPLICATIONS OF POWDER METALLURGY

The powder metallurgy process has provided a practical solution to the problem of producing refractory metals, which have now become the basis of making heat-resistant materials and cutting tools of extreme hardness. Another very important and useful item of the products made from powdered metals is porous self-lubricating bearing. In short, modern technology is inconceivable without powder metallurgy products, the various fields of application of which expand every year. Some of the powder metal products are given as under.

1. Porous products such as bearings and filters.
2. Tungsten carbide, gauges, wire drawing dies, wire-guides, stamping and blanking tools, stones, hammers, rock drilling bits, etc.
3. Various machine parts are produced from tungsten powder. Highly heat and wear resistant cutting tools from tungsten carbide powders with titanium carbide, powders are used for and die manufacturing.
4. Refractory parts such as components made out of tungsten, tantalum and molybdenum are used in electric bulbs, radio valves, oscillator valves, X-ray tubes in the form of filament, cathode, anode, control grids, electric contact points etc.
5. Products of complex shapes that require considerable machining when made by other processes namely toothed components such as gears.
6. Components used in automotive part assembly such as electrical contacts, crankshaft drive or camshaft sprocket, piston rings and rocker shaft brackets, door, mechanisms, connecting rods and brake linings, clutch facings, welding rods, etc.
7. Products where the combined properties of two metals or metals and non-metals are desired such as non-porous bearings, electric motor brushes, etc.
8. Porous metal bearings made which are later impregnated with lubricants. Copper and graphite powders are used for manufacturing automobile parts and brushes.
9. The combinations of metals and ceramics, which are bonded by similar process as metal powders, are called cermets. They combine in them useful properties of high refractoriness of ceramics and toughness of metals. They are produced in two forms namely oxides based and carbide based.

25.6 QUESTIONS

1. What do you under stand by powder metallurgy? What are the main stages of powder metallurgy process?
2. What important considerations should be made in designing the powder metallurgy products?
3. Explain the objectives of powder compaction and list important products of powder metallurgy.
4. Describe briefly the methods by which powders suitable for powder metallurgy can be produced. Also enumerate the main characteristics of metal powder.
5. Describe the atomization process of making powder in detail.
6. What are the effects of sintering on the powder compact produced by pressing?
7. Describe the process of blending, compacting and sintering in detail.
8. What are the effects of sintering on the powder compact produced by pressing?
9. Name the products of powder metallurgy.
10. List the advantages, dis-advantages and applications of powder metallurgy process.
11. It is necessary to use lubricants in the press compaction of powders? Explain.
12. What are 'cermets'? Give a few examples of useful applications
13. State briefly the process of making a powder metallurgy product having improved properties.
14. What are cemented carbides? How are they processed?

26
CHAPTER

INSPECTION AND QUALITY CONTROL

26.1 INTRODUCTION

Inspection or checking of components or products with required specifications is very minutely related with quality control. It is generally an accepted fact that no two things can ever be exactly same. It also holds true with manufactured parts. Therefore certain variations or deviations in dimensions and other product specifications are accepted. However, only few produced articles or parts may be rejected if the deviations go beyond the specified quality standards. Therefore it becomes essential to detect errors so that the manufacturing of faulty product does not go uncorrected. The philosophy of inspection is only preventive and not remedial. In other words the inspection of products is measuring or checking its quality in terms geometrical tolerances of other specified feature of needed design. Generally, there are three basic areas of inspection namely receiving inspection, in-process inspection and final inspection. In the receiving inspection, inspections are performed on all incoming materials and purchased parts. In the in-process inspection the products are inspected as they are in processed in stages from starting station to finished station. In the final inspection, all finished products or parts are inspected finally prior to delivering them to the customer.

The main motive of manufacturing is to process engineering materials and produce desired and useful components or products to the specified shape, size and finish. The specifications for the shapes, sizes and finishes on the products are furnished by the manufacturing operations through specified process plan using part drawings or manufacturing drawings. These specifications basically termed as called quality characteristics. The quality of manufactured product is depend always upon the process capability of controlling manufacturing functions which may lead to a certain amount of variation as a result of chance and some cause. Also some chance or cause is inherent in any particular scheme of production and inspection. The reasons for variation outside this stable system should be discovered and corrected to minimize wastage and finally to improve quality.

26.2 TOLERANCES ON PARTS

It is difficult to manufacture any product or component to its exact size. Tolerance on the parts is therefore the amount of variation in size tolerated to cover reasonable imperfections in workmanship and it varies with different grades of work. Tolerance on a dimension can also be specified as the difference between the maximum limit of size and the minimum limit

of size. It is equal to the algebraic difference between the upper and lower deviations and has an absolute value without sign. Its value is a function of the basic size and is designated by a number symbol, called the grade. There are two basic ways of specifying the working tolerance: (1) bilateral and (2) unilateral, tolerances. Bilateral tolerances are used where the parts vary in both directions from the desired or nominal size. Unilateral tolerances are used where it is important for the dimension to vary in only one direction. Components produced will fall close to the desired dimension but can vary in only one direction. An example is the drilled hole, as the drill is made close to the normal hole size, it is seldom possible to drill a hole undersize. All drilled holes therefore should carry only a plus tolerance. Since the tolerance is allowed on one side of the nominal size, the system is said to be unilateral. Closer the tolerance higher is the cost of product.

26.3 INTERCHANGEABILITY

The dimensions of mating parts are generally controlled to have a proper fitting of matching parts for its optimal functional requirement. Providing dimensions on components or parts is the job of a product designer. Interchangeability of the parts is, therefore, a major pre-requisite for economic production, operation and maintenance of machinery mechanism and instruments. It is therefore very much possible to interchange spare parts in various machines, tractors, motor cars, machines tools, airplanes and many, others so that they can be dismantled for replacement of parts in service conditions in the field, and also in many local workshops with least possible loss of time. In order to produce interchangeable or identical parts, the components of interchangeable system and the various terms related with inter-changeability of the mating parts should be understood clearly by the product designing, manufacturing and product inspecting staff working in industries.

26.3.1 Size

It expresses the numerical value of a length in a particular unit on the part. The basic size of a part is its nominal dimension from where all variations are generally made. It is determined by the part designer from its functional requirements to meet the specified objective. The other term used with respect to a part is the nominal size. The nominal size is the size of the part specified in the drawing as a matter of convenience. It is used primarily for the purpose of identification of a component and is never used in the precision measurement of parts. A rigid attitude towards the maintenance of a basic size of the part may increase the manufacturing cost and a little variation in dimension is accepted resulting in a size, which is different from the basic size of the part. This is called the actual size. The actual size of a dimension or part is its measured size. An actual size of a ready part will, therefore, always deviate from one specified in the drawing, i.e. from the nominal or basic size of the part. Whereas the difference between the basic size and actual size must not exceed from a certain limit otherwise it will interfere with the interchangeability of mating components during assembly or sub assembly of parts.

26.3.2 Limits of Size

Limits of size are two extreme permissible sizes between which the actual size exists. The maximum limit for a dimension is the largest permissible size, while the minimum limit for a dimension is the smallest permissible size. The maximum or minimum sizes represented by tolerances are called the limits. The basic sizes deviation and tolerances for both shaft and hole are illustrated in Fig.26.1.

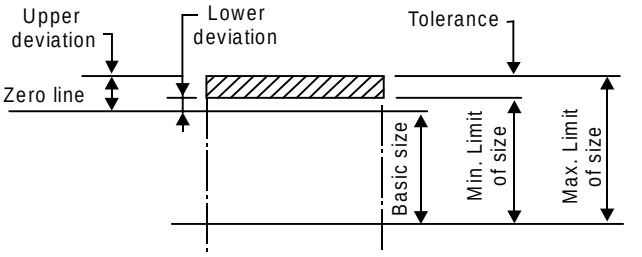


Fig. 26.1 Basic size deviation and tolerances for both shaft and hole

26.3.3 Zero Line and Deviation

In graphical representation of limits, straight line to which the deviations are of zero deviation and the represented of zero deviation are referred. The zero line is also known as line of zero deviation is generally drawn as horizontal line and the positive deviations are shown above this line and the negative deviations below it.

The algebraic difference between the actual or maximum size and the corresponding the basic size is called deviation. The deviations from the basic dimensions at the boundaries of the tolerance zone are called upper and lower deviations as depicted in Fig. 26.2.

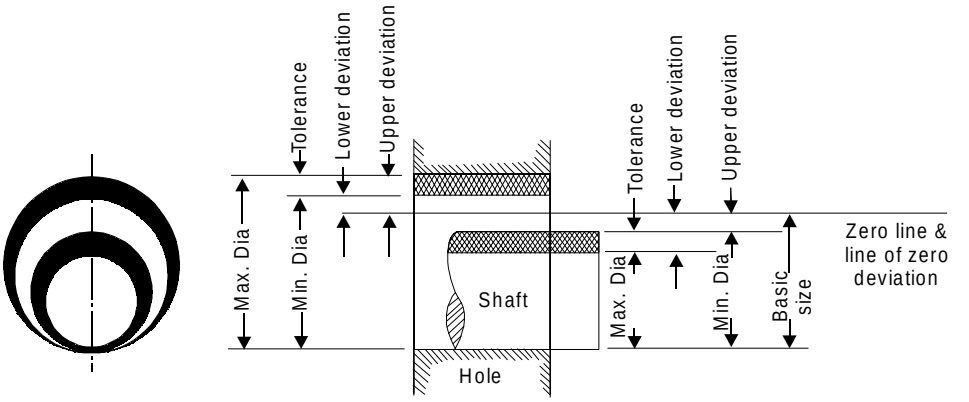


Fig. 26.2 Upper and lower deviations for both shaft and hole

26.3.4 Upper Deviation

It is the algebraic difference between the two maximum limit of any size of the part and the corresponding basic size.

26.3.5 Lower Deviation

It is the algebraic difference between the minimum limit of any size of the part and the corresponding basic size.

26.3.6 Mean Deviation

It is the arithmetical mean between the upper and lower deviations of any size of the part.

26.3.7 Fundamental Deviation

It is the one of the deviations, which is conventionally chosen to define the position of tolerance zone in relation to the zero line. The deviation of the tolerance band on shaft or hole away from the basic size is called the fundamental deviation. It is shown in Fig. 26.3. The zero line shown is the line of zero deviation and represents the basic size. A zero line is a straight line to which the deviations are referred. For conventions, the zero line is drawn horizontally. The positive deviations are shown above and the negative deviations are shown below it.

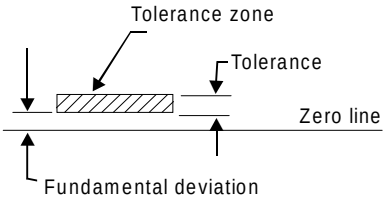


Fig. 26.3 Fundamental deviation

26.4 FITS

26.4.1 Allowance

In a specific type of fit, the difference between hole size and shaft size is called allowance. Allowance is used to explain the difference between clearance fit and interference fit. Positive allowance specifies the clearance fit whereas negative allowance in a fit specifies the interference or force fit.

The relationship existing between two parts, shaft and hole, which are to be assembled, with respect to the difference in their sizes before assembly is called a fit. When the parts are assembled into sub-assembly units and sub assembly units are assembled into full assembly, the mating surfaces of different components are joined together for proper functional requirement. One of them may fit into the other in form of joint or fit. The fit may be with suitable degree of tightness and freedom for required relative movement between mating parts for specific functional requirements of the fit. The classification of fits is given in Fig.26.4.

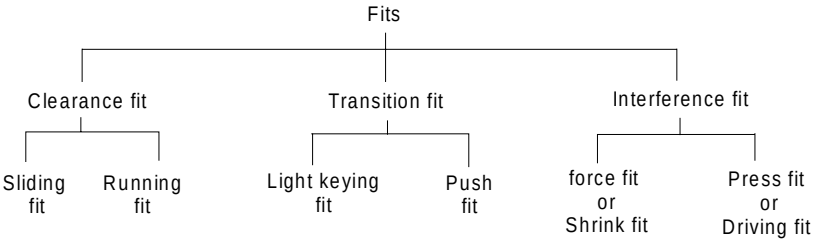


Fig. 26.4 General tree classification of fits

Components are assembled to perform a specific function. The characteristic of the assembly is determined by the fit. Fit is the general term used to signify the relative degree of tightness or looseness of assembled parts, which decides the relative movement between mating parts. Particular type of fit results from the difference in the sizes of mating parts. Fig. 26.5 shows the various types of fits. Two parts can fit each other in three ways, viz.

1. Clearance fit
2. Interference fit
3. Transition fit.

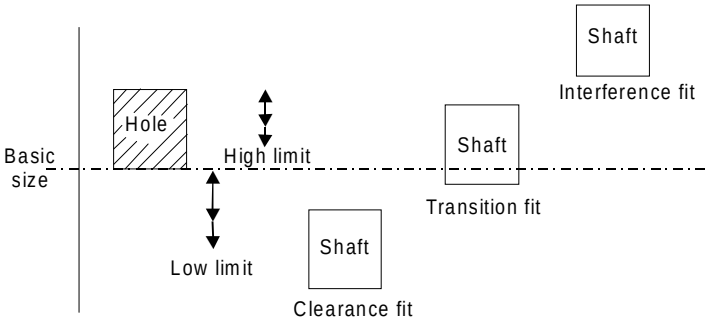


Fig. 26.5 Graphical representation of types of fits

26.4.2 Clearance Fit

Clearance fit is one in which two assembled parts are always free to move relative to each other in the assembly. In the clearance fit, the largest permitted shaft diameter is smaller than the diameter of the smallest hole. The difference between the size of hole and the size of shaft is defined as clearance. Clearance fits have limits of size prescribed so that a clearance always results in a positive allowance, or air space is left between mating parts. The parts can be assembled by hand. Clearance fit is of two kinds namely sliding and running fits. Examples of clearance fit are door hinges, wheel and axle, shaft and bearing, etc. used in the assembly of parts.

26.4.3 Interference Fit

In the interference fit, mating parts in sub assembly or main assembly are joined tightly together and no relative motion is possible. The minimum permitted diameter of the shaft is larger than the maximum allowable diameter of the hole. In this case, the shaft and the hole member in any sub assembly or main assembly is to be attached permanently and used as a solid component but according to the application of this combination, this type of fit can be varied. Interference fit is used for permanent or semi-permanent assembly of parts, which require rigidity and alignment and no relative motion, such as dowel pins and bearings in casting. The difference between the size of shaft and the size of hole in anysub assembly or main assembly is called interference or negative clearance or negative allowance. Interference fit has limits of size so prescribed that interference always results when mating parts are assembled. Transition fits is of two kinds namely driving or press fit and shrink or force fit. To assemble, parts are usually pressed together using an arbor press.

26.4.4 Transition Fit

In this type of fit, the diameter of the largest allowable hole is greater than that of the smallest shaft, but the smallest hole is smaller than the largest shaft, so that small positive or negative clearance between the shaft and hole member is employable. Thus, transition fit has limits of size of hole and shaft such that either a clearance or an interference fit may result when two specific parts from the lot are assembled. Here the tolerance zones of the hole and shaft overlap. Transition fits are a compromise between clearance and interference

fit where a small amount of either clearance or interference is permissible. Transition fit is of two kinds namely push fit and light keying fits. That is, sometimes shaft is slightly larger than the hole and sometimes slightly smaller than the hole. Spigot in mating holes, coupling rings and recesses are the examples of transition fit.

26.5 HOLE BASIS SYSTEM

When hole is kept as constant member and different fits are obtained by varying the shafts sizes in a particular fit shown in Fig. 26.6, then the limit system is known as hole basis system.

26.6 SHAFT BASIS SYSTEM

When shaft is kept as constant member and different fits are obtained by varying the hole sizes as shown in Fig. 26.6, then the limit system is termed as shaft basis system of making sub-assembly or assembly.

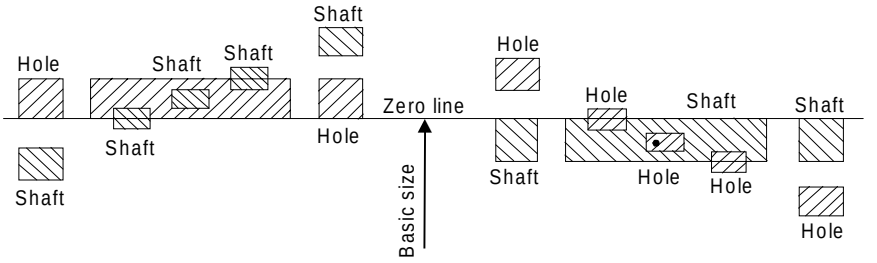


Fig. 26.6 Hole basis system and shaft bases system

26.7 SURFACE FINISH

Good surface finish on part has become an essential requirement of a product quality and for its better life. By imparting a surface finishing process on the part, its dimension does not change functionally and significantly. Either a very negligible amount of material is removed or certain material is added to the surface of the job. Surface finishing processes should not be misunderstood as metal removing processes in any case as they are primarily intended to provide a good surface finish or decorative or protective coating on to the metal surface for its better life and excellent appearance. Surface cleaning process is also accepted as a surface finishing process. Some of the such surface finishing processes are lapping, honing, super finishing, belt grinding, polishing, sanding, tumbling, organic finishes, deburring, electroplating, buffing, metal spraying, painting, inorganic coating, anodizing, parkerizing, galvanizing, plastic coating, metallic coating and anodizing. The characteristics of good finish or roughness of surfaces can be understood by following components, which are described as under.

26.7.1 Roughness (Primary texture)

It refers to relatively finely spaced surface irregularities of small wavelength on the part which results from the inherent action of the manufacturing process. It may involve transverse feed marks and the irregularities on the machined surface.

26.7.2 Waviness (Secondary texture)

It consists of those surface irregularities on the part, which are of considerable wavelength of a periodic character. It may be caused by vibrations, machine or work deflection, chatter, wrapping, etc. It appears in machining operations such as turning, milling, planning shaping, broaching and grinding.

26.7.3 Profile

It is defined as the contour of any section through a surface on the part.

26.7.4 Lay

It is defined as the direction of the predominant surface pattern on the part. It is ordinarily determined by the method used in the production of the article.

26.7.5 Flaws

These are surface imperfections such as minute cavities, holes, porosities, cracks, etc. which appear at frequent intervals and at random locations. The flaws should not be available on the surface.

Some of the well recognized methods for evaluating the roughness of a surface on the parts are centre line average (CLA) method, envelope method and root mean square (RMS) method.

26.8 QUALITY CONTROL

The term quality of product in production processes implies the best for the money invested and does not necessarily mean the best. Therefore quality of the product is the relative term and generally explained with reference to the end use of a product. A product can be referred to be of good quality if it works very well and perform good function in a particular situation for which it is meant or designed while in other situation it may not work well and it is said to be of bad quality. The word control means regulation, which further implies observations and manipulation. It suggests when to inspect, how often to inspect and how much to inspect. The basic philosophy of quality control is both preventive and remedial. Quality control strategy sometime identifies the important check measures and implements them to check so that the defective items are not produced at all. When rejection of products is increasing, some immediate corrective action should be evolved and taken suitably to prevent further recurrence of product rejection of parts. Therefore well-planned inspection will act to be an important tool of controlling quality of products. It checks the products at specified stages while quality control attempts to bring the variable factors of manufacturing under control for achieving the total product specification for meeting customary demands to the maximum possible extent.

26.8.1 Stastical Quality Control

Full inspection of the finished product by usual inspection devices is time consuming and costly. Also in a continuous production process 100% inspection may not be found practicable. Certain statistical techniques have been formulated to evaluate materials, processes and products by observing capabilities and trends in variations so that continual analysis predictions may be made to control the desired quality level of the part. These statistical techniques are called statistical quality control techniques. These techniques are

1. **Control charts for measurable quality characteristics.** These are described as charts for variables, or as charts for X and R (average and range) and charts for average and standard deviation.
2. **Control chart for fraction defective.** This is described as the p chart.
3. **Control chart for number of defects per unit.** This is described as p chart.

26.8.2 Control Charts

Control charts are commonly used in quality control in industries to maintain a continuous evaluation of the manufacturing process. Control chart is simply a frequency distribution of the observed values plotted as points in order of occurrence so that each value has its own identity relative to the time of observation. Points on the control charts may or may not be connected. The chart is provided with limit lines, called control limits, having, in general, one upper control limit and one lower control limit. A process is said to be in control if the observed values are influenced only by chance causes fall within the limits and out of control when assignable causes seem to be operating in the system and the observed value fall outside the limits. It is important that the control limits of the control charts do not represent the performance limit or limits of the manufacturing process nor do these represent the specification limits of the manufacturing drawing of the part. The performance limits of the manufacturing process of the part are the limiting dimensions within which practically all parts fall. If the distribution is normal or near normal, there are three sigma limits of the total distribution in both side and three sigma limits forms the basis of quality control. However, points which fall outside of the control limits do not represent rejected item only signal that some corrective action is essential to check the manufacturing function and hence may lead to control the whole processing process for avoiding wastage involved in rejection of the items.

26.9 ISO 9000

ISO is the International Organization for Standardization based in Geneva, Switzerland. It was founded in 1947 for the purpose of advancing standardization around the world and setting up standards for achieving and maintaining quality. This non-governmental organization now comprises over 130 member countries. Each country is represented by its respective national standards body (for India, it is Bureau of Indian Standards) and participates in developing standards to facilitate trade of goods and services in the global marketplace. The standards developed apply not only to the economic related activities but also cover the related technology and science involved in these pursuits.

ISO 9000 series of internationally recognized quality management standards represents the essential requirements that every enterprise needs to address to ensure the consistent production and timely delivery of its goods and services to the marketplace. Their generic nature allows for their application to any type of organization. Consistency in production and reliability in delivery are as important as what an organization is selling in today's marketplace. It is essential to meet consistently all of the customer's expectations all the time and every time, to keep them satisfied and loyal.

The ISO 9000 series is able to provide these quality management benefits to organizations of any size, public or private, without dictating how the organization is to be run. Certification to an internationally recognized quality management standard like one from the ISO 9000 series is becoming an important part of distinguishing an organization from its competitors.

ISO 9000 is becoming popular because it controls quality and saves money too. A company may decide to use ISO 9000 for many reasons. To develop the system one has to start with gap analysis. A gap analysis will help the enterprise to identify the gaps that exist between the ISO 9000 standard and current processes and will tell exactly what one needs to do to meet the ISO 9000 quality management standard. An enterprise may chose to follow this path because it needs to control or improves the quality of products and services or to reduce the costs associated with quality or to become more competitive. Alternatively, an enterprise may choose this simply because its customers expect it to do so or because a governmental body has made it mandatory.

26.10 QUESTIONS

1. What is the importance of interchangeability in fitting of mating parts?
2. Define the terms: tolerance, allowance, interference and clearance in fits.
3. Illustrate the unilateral tolerance with figures. How is the tolerance specified?
4. Which points you will keep in mind in selecting the tolerance between the piston and cylinder of an engine?
5. Write short notes on the following:

   (*i*) Nominal size (*ii*) Basic size (*iii*) Tolerance (*iv*) Allowance, (*v*) Hole Basis System and (*vi*) Shaft basis system.
6. Write short note on unilateral system of tolerances covering the points-definition, application and advantages over die bilateral system.
7. Describe any system of setting limits and fits.
8. State the importance of limits and fits in production of articles.
9. Give the classifications of fits between the mating parts. What type of fit you will require between the piston rod and stuffing box.
10. Describes the various types of fits.

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